# GEOLOGICAL SURVEY RESEARCH 1963

## Summary of Investigations



GEOLOGICAL SURVEY PROFESSIONAL PAPER 475-A

# Geological Survey Research 1963

THOMAS B. NOLAN, *Director*

GEOLOGICAL SURVEY PROFESSIONAL PAPER 475

*A synopsis of the results of investigations for fiscal year 1963, accompanied by short papers in the fields of geology, hydrology, and related sciences. Published separately as Chapters A, B, C, and D*

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# FOREWORD

Geological Survey Research 1963 is the fourth annual review of the economic and scientific work of the U.S. Geological Survey. As in previous years the purpose of the volume is to bring rapidly to public attention the highlights of results of Survey investigations. This year the volume consists of 4 chapters (A through D) of Professional Paper 475. Chapter A contains the synopsis of results, and the remaining chapters contain short papers as follows:

Prof. Paper 475–B, Articles 1–59
Prof. Paper 475–C, Articles 60–121
Prof. Paper 475–D, Article 122

Many of the results appearing in chapter A are discussed in greater detail in the short papers or in reports listed in "Publications in Fiscal Year 1963" beginning on page A203. The tables of contents for chapters B and C, already published, are listed on page A199, and chapter D is in preparation as this is written. Next year the fifth annual review, Geological Survey Research 1964, will appear as chapters of Professional Paper 501.

During fiscal 1963, numerous Federal, State, County, or Municipal agencies listed on page A247 have cooperated with the Geological Survey and have contributed significantly to the results reported here. They are identified when appropriate in individual articles, although they are not generally identified in the brief statements in Chapter A.

Many individuals on the staff of the Geological Survey have contributed to the current annual review. Reference is made to only a few of them. Joshua I. Tracey, Jr., was responsible for organizing and assembling material and for the critical review of articles. He was assisted by George H. Davis, who assumed particular responsibility for material from the Water Resources Division. Marston S. Chase was assisted by Jesse R. Upperco, in technical editing and in the preparation of indexes, and by William H. Elliott, in the planning and preparation of illustrations.

Thomas B. Nolan

THOMAS B. NOLAN,
*Director.*

# Summary of Investigations

## GEOLOGICAL SURVEY RESEARCH 1963

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*A summary of recent scientific and economic results, accompanied by a list of publications released in fiscal 1963, a list of geologic and hydrologic investigations in progress, and a report on the status of topographic mapping*

UNITED STATES GOVERNMENT PRINTING OFFICE, WASHINGTON : 1963

**UNITED STATES DEPARTMENT OF THE INTERIOR**

**STEWART L. UDALL, *Secretary***

**GEOLOGICAL SURVEY**

**Thomas B. Nolan, *Director***

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# ILLUSTRATIONS

# INVESTIGATIONS OF NATURAL RESOURCES

Mineral, fuel, and water resources constitute much of the Nation's basic wealth, and the U.S. Geological Survey has the chief responsibility for ascertaining their distribution and quality. The demand for these resources is continually changing and always growing. In response to the demand for information on natural resources the Survey is placing increasing emphasis on compilation and analysis of resources information, and is accelerating research on problems bearing on the discovery, appraisal, and effective development of these resources. Water, for the most part, is a renewable resource, whereas minerals and fuels, for practical purposes, are nonrenewable.

## MINERAL RESOURCES

Most of the investigations of mineral resources, including fuels, made by the Geological Survey can be grouped into (a) district and regional studies and (b) commodity and topical studies. The district and regional studies are focused on areas known or thought to contain mineral resources; their purpose is to establish guides useful in the search for concealed deposits, to define areas favorable for exploration, and to appraise known and potential resources. Most studies of this kind involve geologic mapping, and many of them ultimately help to develop general principles of wide application. The commodity and topical studies deal with the appraisal of national resources of various minerals, the synthesis of empirical data on ore habits that help to define environments favorable for the occurrence of useful minerals, and experimental and theoretical studies of the origin and distribution of such minerals. The long-range aims of both groups of studies are to obtain data on field relations and theoretical principles that will provide a foundation from which private industry can extend its search for usable raw materials, and that will provide the Nation as a whole with a continuing appraisal of its mineral wealth.

Special attention is being given to defining new sources of previously little-used minerals for which new uses have created or are likely to create important demands.

Better understanding of the geochemical, geophysical, and geologic processes involved in the formation and localization of mineral deposits is essential to the improvement of prospecting, and marked success is being achieved by interdisciplinary approaches in the search for minerals.

### Mineral-occurrence maps of the United States

Several new maps of the conterminous United States, showing the locations of the important mineral-bearing areas, prepared under the direction of W. L. Newman, have been published in the Mineral Resources series: MR 34–silver, MR 35–beryllium, MR 36–niobium and tantalum, and MR 37–high alumina clay.

The maps are printed at a scale of 1:3,168,000, and each is accompanied by a pamphlet that describes the geologic occurrence and use of the mineral commodity. The pamphlet also contains an index to the mineral-bearing areas and a selected bibliography. Previously published mineral-occurrence maps show copper, vanadium, lead, uranium, zinc, antimony, gold, tungsten, mercury, chromite, bismuth, thorium, rare earths, titanium, borates, pyrophyllite and kyanite, manganese, asbestos, magnesite and brucite, gypsum and anhydrite, and talc and soapstone. Maps of about a dozen other mineral commodities are in various stages of preparation. This series of maps will serve as a basis for testing regional metallogenic concepts.

A map showing the location of placer gold deposits in Alaska has been prepared by E. H. Cobb. This map will be the sixth of a series of mineral-occurrence maps of Alaska (scale 1:2,500,000) to be published in the Mineral Resources series. Previously published maps of Alaskan deposits include lode gold and silver, chromite-cobalt-nickel-platinum-group metals, copper-lead-zinc, molybdenum-tin-tungsten, and antimony-bismuth-mercury. Maps of several other mineral commodities are in various stages of preparation.

The mineral-occurrence work has been expanded to include mineral occurrences throughout North America, in cooperation with Canadian and Mexican counterpart organizations under the general program of the Subcommission for the Metallogenic Map of the World, International Geological Congress.

#### Study of Nation's silver production

Silver production in the United States as it is affected by recent price increases has been reviewed by E. T. McKnight (1–62).[1] He emphasized the relatively greater importance of silver in the early history of many western mining districts. All the major silver districts were in full production by 1890 and no new major silver districts have been discovered since 1900. Because of depletion, many of the former silver-producing districts are not longer significant producers. Most of the U.S. silver is now a byproduct or coproduct of base-metal ores, and few mines are worked mainly for silver. Gold ores have produced less silver than lead and copper ores. Any significant rise in the price of silver will encourage development of base-metal ores that contain appreciable silver, but the number of mines whose production would be stimulated by a rise in price of silver is small. No large increase in U.S. production could be expected if the price of silver were raised considerably above the present level.

#### Resources of Montana summarized

The U.S. Geological Survey (21–63), in cooperation with the Montana Bureau of Mines and Geology, has summarized the mineral and water resources of Montana. Known and potential mineral and mineral-fuel raw materials (including among the heavy metals chromium, copper, gold, iron, manganese, molybdenum, silver, lead and zinc, tungsten, and others) are described, located on maps, and discussed in terms of the economic and geologic factors that may affect their further development and use.

## HEAVY METALS

### IRON

#### Aeromagnetic studies in Michigan

Aeromagnetic studies of the Upper Peninsula of Michigan are providing new information on the metamorphosed sedimentary iron-formations and associated rocks. J. E. Gair and J. E. Case find that magnetic anomalies in the Marquette district are related to four groups of rocks: (1) prominent highs of up to 20,000 gammas occur over magnetic iron-formation of the Animikie Series; (2) discontinuous highs of up to 8,000 gammas are found over serpentinized peridotite; (3) the pre-Animikie gneissic basement is characterized by discontinuous highs and lows of low to moderate amplitude, and the magnetic contours generally parallel the grain of the rocks; and (4) large magnetic lows are associated with east-trending negatively polarized Keweenawan diabase dikes. These magnetic characteristics enable major rock units to be traced beneath glacial cover with some confidence.

A restudy of the Gogebic Range in cooperation with the State was initated in 1962.[1a] Aeromagnetic surveys in conjunction with geologic mapping show, in addition to an anomaly over the eastern end of the principal iron-formation belt, a number of magnetic features south of the belt. Some, which were known in a general way from old ground surveys, are associated with iron-formation of the Marenisco and Turtle Ranges; others are in areas of very poor exposures and cannot yet be ascribed to known geologic features.

#### Iron deposits in Montana

K. L. Wier reports that the Black Butte iron deposit in the Gravelly Range, Madison County, Mont., is, like nearby deposits, a metamorphosed sedimentary quartz-magnetite iron-formation of Precambrian age that occurs with quartzite, mica-staurolite-andalusite schist, metadiabase, and metagabbro. The iron-formation appears to be about 50 feet thick; it is, however, tightly folded in places and faulted into segments. Thick Paleozoic sedimentary rocks conceal any northwestern extension, and Tertiary volcanic rocks cover the southeastern end.

#### Iron ore in Nevada

The iron that was deposited by hydrothermal processes in a volcanic sequence of Jurassic(?) age in the northern Cortez Mountains, Eureka County, Nev., probably was derived from nearby Early Cretaceous(?) intrusive rocks during the deuteric stage of their crystallization, according to L. J. P. Muffler.[2] Extensive sericitization and kaolinization of the host rock accompanied the mineralization.

#### Magnetite deposits in Alaska

The presence of several pyrometasomatic magnetite deposits in the North Bradfield River area of southeastern Alaska is reported by E. M. MacKevett, Jr.,

[1] Articles in chapters B and C of Professional Paper 475 are cited as follows: Sundelius (Art. 12); contents of these chapters are listed by article number, beginning on page A199. References to other reports published in fiscal year 1963 are cited as follows: McKnight (1–62), which is the first citation for McKnight for the year 1962, in the list of publications starting on page A203. All other references are given in footnotes.

[1a] Philbin, P. W., and Vargo, J. L., 1963, Aeromagnetic map of central Gogebic County, Michigan, and vicinity: U.S. Geol. Survey open-file report.

[2] Muffler, L. J. Patrick, 1962, Geology of the Frenchie Creek quadrangle, north-central Nevada: U.S. Geol. Survey open-file report, 175 p., 2 pl., 34 figs.

and M. C. Blake, Jr.[3] The deposits occur in skarn together with gneiss, granulite, schist, and marble that make up a northwest-trending roof pendant in the composite Coast Range batholith.

## COPPER

### Buried intrusive body near Ely, Nev.

A combined geochemical-geophysical-geologic study in eastern Nevada by A. L. Brokaw, G. B. Gott, D. R. Mabey, and J. H. McCarthy, Jr. (1–62, 2–63) has indicated the possibility of important new ore deposits near the Ely mining district. Geologic mapping revealed structural irregularities and rock alteration, suggesting that the Ward Mountain area of the Egan Range contains concealed intrusive rocks and possibly accumulations of metals of economic value. An aeromagnetic survey made to test this hypothesis revealed a large magnetic anomaly similar to that caused by the mineralized intrusive body near Ruth, Nev. This discovery prompted a geochemical study which showed anomalous concentrations of silver, molybdenum, copper, and several other metals in jasperoid (altered limestone) and iron-rich fracture fillings along and adjacent to major faults directly over the magnetic anomaly. These high concentrations of metals may represent a leakage halo from metal deposits in and near the postulated buried intrusive.

### Arizona

In the Pima copper district, Arizona, large-scale mapping by J. R. Cooper has yielded structural data of possible importance in the search for concealed deposits. In and near the San Xavier mine, Paleozoic rocks contain slices of Cretaceous(?) rocks in an imbricate pre-ore fault zone that trends east and is bordered on the south by a large parallel syncline of Cretaceous(?) rocks. East of the mine, in the Helmet Peak area, the imbricate zone extends south in a narrow anticline that pierces the Cretaceous syncline normal to its trend. If one removes post-ore rotation indicated by the present attitude of the Helmet Fanglomerate of Miocene(?) age, the structure suggests nappes that rode northeastward and were in part buckled up later in a diapir fold. If this interpretation is correct, the fault zone mineralized at the San Xavier mine must continue somewhere to the east where bedrock is almost entirely concealed by alluvium.

Isotopic ages determined on 13 igneous rocks in 7 copper-mining districts in Arizona are reported by S. C. Creasey and R. W. Kistler (1–62). In 6 of these districts, rocks that antedate the deposition of ore range in age from 72 to 56 million years; as geologic evidence favors a reasonably close spatial and temporal relationship of these rocks to the ores, these dates afford support for the concept of a Laramide (early Tertiary) period of mineralization in southeastern Arizona. In the 7th district, at Bisbee, a granitic rock was dated at about 170 m.y., but its relation to the ore is uncertain and no unequivocal dating of mineralization is yet possible.

### Idaho

In the Lemhi Pass area, Lemhi County, thorite- and copper-bearing veins contain up to 2 percent $ThO_2$ and may have economic value. W. N. Sharp and W. S. Cavender (1–62) distinguish four types of veins: (1) quartz-hematite-thorite, (2) quartz-copper sulfide-thorite, (3) quartz-copper sulfide, and (4) quartz-hematite veins. Most are small, but a few range up to 30 feet in width and several hundred feet in length.

### Southeastern United States

Cupriferous pyrite or pyrite-pyrrhotite deposits occur in a variety of metamorphosed rocks in the Blue Ridge and Piedmont provinces. According to Espenshade[4] the Fontana and Hazel Creek deposits, Swain County, N.C., are in phyllite; the Toncrae deposit, Floyd County, Va., is in garnet-quartz-mica gneiss; and the Stone Hill deposit, Cleburne and Randolph Counties, Ala., is in hornblende schist. The deposits range from tabular lenses to elongate pods that parallel lineation in the enclosing rock.

Rubidium-strontium and potassium-argon age determinations have been completed on vein hornblende and on vein and wall rock biotite at the Ore Knob copper mine, North Carolina, by H. Thomas, R. F. Marvin, F. G. Walthall, and C. E. Hedge of the U.S. Geological Survey. These indicate that the ore deposit was formed in middle Precambrian time and was subjected to 2 periods of metamorphism tentatively placed at about 330 and 450 m.y. ago. This confirms geologic evidence of metamorphism of the ore previously reported (Kinkel, 1–62).

## LEAD, ZINC, AND RELATED ORES

### Central and Eastern States

Continuing studies of various aspects of the so-called Mississippi-Valley-type deposits have brought out further details of the occurrence of these ores and of the structures associated with them. For example, T. H. Kiilsgaard, A. V. Heyl, and M. R. Brock (1–63) de-

[3] MacKevett, E. M., Jr., and Blake, M. C., Jr., 1963, Geology of the North Bradfield River iron prospect, southeastern Alaska: U.S. Geol. Survey Bull. 1108–D. [In press]

[4] Espenshade, G. H., 1963, Geology of some copper deposits in North Carolina, Virginia, and Alabama: U.S. Geol. Survey Bull. 1142–I. [In press]

scribe shatter cones, intrusive breccias, and post-breccia sulfide mineralization at the Crooked Creek disturbance in southeast Missouri. The location of the disturbance at the intersection of regional faults, and its internal structures indicate to them that the disturbance was caused by a subterranean gaseous explosion rather than by meteorite impact as some have suggested. The same men have also examined the Decaturville disturbance about 70 miles to the west and find that it is probably also located at the intersection of region-wide structures. The latter disturbance shows many of the same features; it has undergone at least three well-defined periods of brecciation and mineralization.

Heyl and his coworkers point out apparent relationships between many of the zinc, lead, fluorite, and barite districts of the central craton and major tectonic features, including broad folds, extensive fault systems, seismically active zones, and perhaps alkalic intrusions. Some of these features were compiled on a "Preliminary Metallogenic Map of Part of the Eastern United States and Canada" that was exhibited in Paris at the meeting of the Commission for the Geologic Map of the World in December, 1962.

Clay-alteration studies by X-ray analysis have been carried out by A. V. Heyl, John Hosterman, and M. R. Brock on specimens collected from zinc deposits in southwestern Wisconsin. Illite, muscovite, and mixed-layer clays formed in the deposits, and these minerals extend outward in decreasing quantities beyond the margins of alteration halos of dolomite. Preliminary results suggest that similar clays occur in the Kentucky-Illinois fluorite-zinc district.

Recent fieldwork by D. M. Pinckney in the Cave-in-Rock area of the Kentucky-Illinois district supports the theory that ore-depositing solutions reached the limestone host rock from depth through fractures or pipelike slump areas due to solution of the limestone. Detailed mapping shows that early minerals are localized near the feeder structure, whereas later minerals or later stages of a given mineral extend farther from the points of ingress of the solutions.

T. H. Kiilsgaard finds that geochemical study of soil samples from the southeast Missouri lead district does not reveal anomalous concentrations of copper, lead, zinc, or cobalt along the faults of the district, either above known ore deposits containing these metals or away from them.

### Replacement deposits, Eureka, Nev.

In a comprehensive report on the Eureka mining district, Nevada, T. B. Nolan (1–62) describes the ore bodies at Eureka as among the first of the large replacement deposits in carbonate rocks to be mined extensively in the West. Peak production from the district was in the interval 1870–90, and total value of metals mined since 1866 is estimated at about 122 million dollars. The replacement bodies are of 5 general types: irregular replacements, bedded replacements, fault-zone replacements, disseminated deposits, and contact metasomatic deposits. Most of the ore has come from the irregular replacement deposits, chiefly from the Eldorado Dolomite of Middle Cambrian age. Almost all the production has been lead, silver, and gold from oxidized ores. Below the water table are sulfide ores having a much higher zinc content, but attempts to mine them have been hampered by great volumes of water.

### Exploration in East Tintic district, Utah

Continued drilling by private interests in the East Tintic mining district, Utah, has disclosed the concealed position of the ore-localizing East Tintic thrust fault to a point 1½ miles north of the area where it was discovered by the Bear Creek Mining Co. through application of principles developed by the Geological Survey.[5] Several exploration holes drilled during the latter half of 1962 intercepted ore bodies of commercial size and grade close to the thrust in a previously unexplored area. These ore bodies are as far as a mile from the nearest previously known ore bodies and represent entirely new discoveries. Additional holes are currently being drilled to evaluate the discoveries and to determine the extent of the mineralization as well as to trace the thrust fault beneath the lava flows that conceal it.

### Darwin district, California

According to W. E. Hall and E. M. MacKevett, Jr., (1–62) lead-silver-zinc deposits in the Darwin district, Inyo County, Calif., are bedded replacements, veins, and pipelike masses in limestone near a quartz monzonite intrusion. Near the surface the sulfide ores have been largely oxidized to limonite, jarosite, cerussite, and hemimorphite; at depth the ratio of zinc to lead increases and silver is less abundant. Since 1942 most production has come from the sulfide ores, chiefly from the Darwin mine.

## GOLD AND SILVER

### Central City, Colo.

P. K. Sims and P. B. Barton, Jr. (1–62) call attention to well-defined concentric zones of gold, silver, and base-

[5] Lovering, T. S., and Morris, H. T., 1960, U. S. Geological Survey studies and exploration, pt. 1, *in* Bush, J. B., Cook, D. R., Lovering, T. S., and Morris, H. T., The Chief Oxide–Burgin area discoveries, East Tintic district, Utah, a case history: Econ. Geology, v. 55, no. 6, p. 1116–1147.

metal deposits in the Central City district, Colorado. A core of pyrite-quartz veins is surrounded by an outer zone of veins containing dominant galena and sphalerite in a gangue of quartz or, less commonly, rhombohedral carbonates, barite, or fluorite. Veins in the transitional area contain pyrite, copper minerals, galena, and sphalerite. Systematic changes in gold and silver content, in metal ratios, and in mineral textures mark the transition from the core outward. Most of the sulfide ore and the gold and silver were deposited in the intermediate and peripheral zones of the district.

#### Gold in Wyoming

Geologic mapping recently completed by R. W. Bayley in the Atlantic district, Fremont County, Wyo., has shown that, with few exceptions, the gold deposits of the district are related to shear zones within and marginal to a prominent belt of metagabbro that trends northeasterly across the district. Eighty assays of samples taken from test pits along the belt indicate that the exposed quartz veins are generally barren. Without a known exception the areas of valuable ore were found by the early explorers, and these areas are now marked by numerous abandoned shallow mines. There is doubtless gold in the ground but it apparently cannot be mined at a profit by the methods used in the past. The future of the district as a gold producer would seem to depend on the consolidation of contiguous properties and the intelligent development of deep mines by utilizing all modern techniques.

### MERCURY

#### Hot-springs deposits in California

The Sulphur Bank mercury deposit in California, studied by D. E. White and C. E. Roberson (1–62), is the most productive deposit in the world that is clearly related to hot springs. The ore is late Quaternary and is localized immediately below the water table in andesite. Native sulfur without cinnabar was abundant near the surface, but as mining approached the water table, the amount of sulfur decreased and cinnabar became abundant. The principal ore bodies were at and below the water table; they consisted of cinnabar, marcasite, pyrite, dolomite, calcite, quartz, a zeolite mineral, and all the minerals of the original rocks. Metacinnabar and stibnite were locally common.

The present rate of discharge of water of deep origin is calculated to be about 50 gpm. Present temperatures are relatively low compared with those of other hot-spring systems of clearly volcanic origin. The heat flow is on the order of 200,000 cal per sec, or about 12 times "normal" for the area. The heat is almost certainly volcanic in origin, but, despite association with Quaternary volcanic rocks and volcanic heat, the chemical and isotopic compositions of the water and gases now being discharged indicate that these fluids are nonvolcanic in origin.

#### Cinnabar in Alaska

A new occurrence of cinnabar was found by J. M. Hoare and W. H. Condon while mapping the geology of the Holy Cross quadrangle in western Alaska. Thin films of drusy cinnabar with small blebs of stibnite occur in highly altered rhyolite in a small area about 2 miles northwest of Wolf Creek Mountain. The find extends the known area of quicksilver mineralization about 100 miles northwest from previously known occurrences in the vicinity of the Iditarod and Kuskokwim Rivers. Specimens obtained from the locality do not contain commercial quantities of the metal, but they show that quicksilver mineralization is present and suggest that careful prospecting of the area, much of which is underlain by hydrothermally altered rhyolite, may reveal minable deposits.

### TOPICAL STUDIES

#### Structural control of ore deposits in Idaho

B. F. Leonard has found that the central segment of a major silicified zone on Big Chief Creek, Yellow Pine quadrangle, Idaho, shows pinching and swelling similar to that previously mapped in the parallel Johnson Creek silicified zone which lies 8 miles to the west. Deposits of gold, antimony, and tungsten occur in bulges in the Johnson Creek zone. This suggests that similar bulges in the Big Chief zone may be favorable sites for ore deposition. Only the narrow interbulge segments of this zone have previously been prospected. Much of the zone is deeply weathered; other parts are covered by glacial debris.

#### Rutile in metamorphosed carbonate bodies in Idaho

R. L. Parker reports that rutile is present in metamorphosed carbonate bodies near Acorn Butte, lower part of Big Creek, Valley County, Idaho. The metacarbonatites(?) are separated from the Ramey Ridge Complex of saturated alkalic syenite (Leonard, 1–63) by metasedimentary rocks and by coarse hornblende-bearing rocks that may represent either mafic alkalic intrusives or old metavolcanics reconstituted during emplacement of the syenite complex. The relations between metacarbonatite(?) and uncontaminated facies of the Ramey Ridge Complex have not been determined, but the bodies near Acorn Butte are somewhat like those studied by E. P. Kaiser, R. L. Parker, and others on the West Fork of the Bitterroot River, Ravalli County, Mont., and north of Shoup, Lemhi County, Idaho.

### Use of isotopes in exploration in Utah

Studies by T. S. Lovering, J. H. McCarthy, and Irving Friedman (Art. 1) of the isotopic composition of oxygen and carbon in carbonate rocks and manganese carbonate replacement ore in the Drum Mountains of Utah show that within a single bed the $O^{18}/O^{16}$ per mil (°/₀₀) values may range from +5.0 to +19.0, a range of 14°/₀₀. The range of $C^{13}/C^{12}$ ratios within a single bed is no more than 0.9°/₀₀, but the averages of the $C^{13}/C^{12}$ for the individual beds range from +0.1°/₀₀ to −3.2°/₀₀ for the six beds sampled. Where the changes in the carbon isotopes are substantial in a vertical sequence of beds, the $C^{13}/C^{12}$ ratios may help greatly in solving correlation problems, especially in comparing altered carbonate strata with the unaltered strata, both in drill core and in outcrop. The change in the $O^{18}/O^{16}$ ratio is clearly related to distance from hydrothermal conduits, the $O^{18}/O^{16}$ value decreasing as the source or conduit is approached. This change must reflect the equilibration of the oxygen of the original carbonate with the hot aqueous solutions that altered the rock. The lack of change in the $C^{13}/C^{12}$ ratio suggests that the hot solutions originally carried almost no soluble carbon compounds and, as neither fluorite nor anhydrite is present, the hydrothermal solution that changed the limestone to dolomite and the dolomite to manganese carbonate was probably a chloride solution, low in $CO_3^{-2}$, $SO_4^{-2}$, and $F^{-1}$.

## LIGHT METALS AND INDUSTRIAL MINERALS

### BERYLLIUM

The highlight of a diverse series of investigations involving beryllium was the discovery by C. L. Sainsbury of new deposits in the Lost River area, western Seward Peninsula, Alaska. Study of beryllium associated with granitic rocks in central Colorado was continued by C. C. Hawley and W. N. Sharp. Interest in beryllium associated with volcanic rocks continues to be generated by exploration activity in which several companies are engaged, especially at Spor Mountain, Utah. U.S. Geological Survey work on the distribution of beryllium in volcanic rocks throughout the West indicates that metallogenic provinces in beryllium can be recognized. These and other beryllium investigations have been greatly aided by design refinements in the gamma-neutron beryllium analyzer installed at Denver, Colo., with which as little as 1 part per million beryllium can be detected.

#### Beryllium in Alaska

The beryllium deposits of the Lost River area, Alaska, which previously had been known mainly for its tin, are described by Sainsbury[6] as replacement bodies taking the form of veins, pipes, and irregular stringer lodes. Analyses of bulk samples of ore range from 0.11 to 0.54 percent beryllium. Four mineralized areas have been recognized in a zone 7 miles long by 2 to 3 miles wide. The dominant beryllium minerals are chrysoberyl and euclase, but additional beryllium minerals have also been detected. The modal composition of typical ore is fluorite (45–63 percent), diaspore (5–10 percent), tourmaline (0–10 percent), and mica (0–5 percent). The host rock is limestone, which has been faulted and intruded by rhyolite and diabase dikes and by granite stocks. Geochemical reconnaissance indicates that other areas in the Seward Peninsula have an anomalously high content of beryllium in stream sediments; more discoveries of ore deposits in nearby rocks may be anticipated.

#### Beryllium with tin in Virginia

The tin locality at Irish Creek, Va., resembles the Lost River area, and for this reason has been sampled to ascertain its potential for beryllium. Results reported by F. G. Lesure and others (Art. 3) show that there is indeed enough beryllium to warrant more thorough exploration at Irish Creek.

#### Beryllium-rich granites in Colorado

Investigations of beryllium-rich granites and their late magmatic derivatives have been made mainly in parts of the Pikes Peak batholith of the Front Range and in the Mount Antero Granite of the Sawatch Range, Colo. Only the Boomer mine, which is in a quartz-beryl vein near Lake George, Colo., has thus far been productive, but other localities are either of potential economic value or will at least serve to clarify petrogenetic problems involved in the development of beryllium-rich rocks.

At Mount Antero, leucocratic granite forms a well-defined stock, roughly oval in shape, and 3 by 4 miles in dimensions at the surface; it is accompanied by dikes and other satellitic bodies that are lithologically similar to the main intrusive but have a smaller grain size. W. N. Sharp finds that virtually all of the significant concentrations of beryllium are in the western part of the main intrusive and in nearby satellites. In this area the granite has miarolitic cavities and pegmatites, and is in part altered to clay, carbonate, or siliceous materials. These characteristics, together with quartz veins and greisen in the country rock and in satellitic intrusives, suggest the influence of late mag-

[6] Sainsbury, C. L., 1962, A new occurrence of beryllium minerals on the Seward Peninsula, Alaska: U.S. Geol. Survey open-file rept., 10 p.
——— 1963, Beryllium deposits of the western Seward Peninsula, Alaska: U.S. Geol. Survey Circ. 479, 18 p.

matic fluids, largely gaseous. Beryllium minerals occur in the granite and in its miarolitic cavities, as well as in the pegmatites and quartz veins. Beryllium minerals probably also are in topaz-molybdenite greisens, but the data from these are not yet complete. Beryl-rich aggregates in granite contain most of the beryllium thus far detected; the largest of these are only about 15 feet in diameter.

An association of beryllium with late magmatic derivatives and metasomatic products is also noticeable in the Mount Rosa area, El Paso County, Colo. Here beryllium is found in notable amounts in red-brown masses filling spaces between quartz and feldspar in altered pegmatitelike bodies associated with the Mount Rosa Granite, which is a facies of the Pikes Peak Granite. The red-brown material is a finely layered mixture of quartz and hematite-stained bertrandite. It probably formed by alteration of primary astrophyllite and beryl.

Continued study of the Lake George area, Colorado, by C. C. Hawley [7] has further clarified the geology of beryllium-bearing greisens that are associated with medium- to fine-grained late phases of the Pikes Peak Granite. Age determinations by K–Ar and Rb–Sr methods and isotopic analysis of galena confirm that the fine-grained varieties of granite, muscovite in the greisens, and galena from the Boomer mine are all of approximately the same age as the Pikes Peak batholith. The late varieties of granite form simple and composite plutons emplaced in the typical coarse-grained Pikes Peak Granite and in older igneous and metamorphic rocks. Two plutons were recognized previously, one a lobelike body about 4 miles across, extending southward from the main Pikes Peak batholith, and the other a small stock at the Boomer mine. The stock is only about 500 feet wide on the surface, but mine workings driven in 1962 show that it is about 900 feet across at a depth of 100 feet, thus effectively enlarging the prospecting area near the Boomer mine. A third pluton about half a mile across was mapped during 1962. Beryllium deposits in the newly mapped pluton are in or adjacent to fine-grained granite very similar to that forming the stock at the Boomer mine.

The late varieties of granite are rich in fluorine; one facies averages 0.47 percent F, and other facies are only slightly less rich in fluorine. In the main pluton of the area, progressively younger facies of the granite are characterized by decreasing amounts of silica and potash and increasing amounts of soda, and by a higher muscovite-biotite ratio and lower amounts of plagioclase relative to potassic feldspar. Fine-grained granite, which occurs locally as a border facies of the main pluton and is also found in the two smaller plutons, is appreciably more silicic and sodic than the granite facies of the main pluton, or indeed than most magmatic granites. It contains abundant late quartz, albite, and locally muscovite, and it is associated with beryllium-bearing greisen. The progressive changes are consistent with a working hypothesis that the volatile material tended to accumulate in the magma at a late stage to form rocks richer in soda and muscovite than those which crystallized from earlier and drier magma. The ultimate effect locally was to produce aqueous, fluorine-rich residual solutions that formed greisen pipes, veins, and irregular bodies.

The beryllium-bearing greisens consist mainly of BeO, $SiO_2$, $Al_2O_3$, $K_2O$, and ($H_2O$, F), which are present in the minerals beryl, bertrandite, topaz, muscovite, and quartz. These ore-bearing greisens generally occur within an envelope of barren greisen, which carries appreciable amounts of FeO, $Fe_2O_3$, and CaO. The dominant mineral assemblages of the ore-bearing greisens are quartz-beryl-muscovite and quartz-bertrandite-muscovite; others are quartz-beryl-topaz-muscovite and quartz-beryl-bertrandite-muscovite. The quartz-bertrandite-muscovite assemblage is largely secondary after assemblages containing beryl. In places, however, it appears to be the primary beryllium-bearing assemblage.

**Beryllium associated with fluorine**

The association of beryllium with fluorine has been of special interest in work on volcanic rocks. The content of beryllium and fluorine has been determined (Coats and others, 2–62; Coats and others [8]), as well as the content of several other elements, in about 175 samples of rhyolitic and rhyodacitic Tertiary volcanic rocks, mostly glassy, collected in Washington, Oregon, California, Idaho, Nevada, Arizona, Montana, Wyoming, Utah, Colorado, New Mexico, and Texas. Both elements have log-normal distribution, and there is a strong positive correlation between them. The regional distribution of these elements is nonrandom, and suggests that metallogenic provinces in which beryllium occurs can be delineated. The highest values are mainly in west Texas, west-central New Mexico, south-central Colorado, and in a region including western Wyoming, western Utah, northeastern Nevada, and southeastern Idaho. The distribution of beryllium in volcanic rocks may give clues to the location of areas

[7] Hawley, C. C., 1963, Genetic relation of Pikes Peak Granite and beryllium-bearing greisens, Lake George area, Park County, Colo.: Geol. Soc. America, Rocky Mtn. Sec., 16th Ann. Mtg., Albuquerque, N. Mex., Program, p. 28.

[8] Coats, R. R., Goss, W. D., and Rader, L. F., 1963, Distribution of fluorine in unaltered silicic volcanic rocks of the western conterminous United States: Am. Jour. Sci. [In press]

where minable deposits of beryllium minerals may be expected to occur.

A study of 170 samples of silicic volcanic glass, reported by Griffitts and Powers (Art. 5), also shows a correlation between the content of beryllium and that of fluorine. They find, however, that suites of genetically or geographically related samples may not have the unimodal log-normal distribution found in the more heterogeneous group of samples used by Coats and others.

At Spor Mountain, Utah, the high fluorine content of the rocks has long been known. In fact, its presence played a role in attracting exploration geologists who suspected that it might be a useful guide in the search for beryllium, and in this way it contributed to the original beryllium discoveries in 1959 and 1960. W. R. Griffitts and L. F. Rader (Art. 4) have now published the results of a quantitative study of the relation between beryllium and fluorine in the mineralized tuffs of this locality. They found not only that there is a direct correlation between the content of beryllium and the content of fluorine, but also that the samples are grouped in two concentration ranges—1,000 ppm beryllium or more in ore, and 100 ppm beryllium or less in widespread altered rock elsewhere. The maximum beryllium content probably lies between 7 and 10 percent, associated with a fluorine content of about 30 percent.

A detailed map and a description of the Spor Mountain deposits and their geologic setting have been made by M. H. Staatz (2–63). These deposits are spatially associated with a thick sequence of topaz-bearing rhyolitic flows and pyroclastic rocks, and the fluids from which they were formed seem to have been derived from the rhyolitic magmas during the waning stages of volcanism. Staatz argues that the beryllium was carried as a soluble complex fluoride, and that the fluoride rose along the faults of the western part of the Thomas Range. The fluids formed fluorspar deposits in the central part of the district, but as the fluoride content of these fluids was still high, the beryllium complex did not break down. As the fluids moved into the outlying regions, the fluoride content was reduced and the beryllium precipitated.

#### Relation of beryllium to chemical content of rocks

D. R. Shawe and Stanley Bernold have been compiling data on igneous rocks from all over the world for which there are both chemical analyses for major components and spectrographic analyses for beryllium. Preliminary results indicate that this approach may cast light on the relation of beryllium content to chemical composition, geologic setting, and geographic location of the rocks. The approach should also serve to clarify the role of magmatic differentiation in concentrating beryllium. Though this work partly confirms the established belief that beryllium tends to be enriched in silicic and alkalic rocks, it also shows that for rocks with an unusually high beryllium content there is a reversal such that silica and alkali decrease as beryllium increases. Furthermore, hypabyssal and plutonic rocks tend to be richer in beryllium than volcanic rocks. Both of these observations cast suspicion on the concept that magmatic differentiation of igneous rocks is virtually the sole means of concentrating beryllium and controlling its distribution. The distribution of volatiles may be more important. Beryllium, wherever it is abundant in plutonic rocks, is in pegmatites, greisens, and allied rocks that were high in volatiles that could not escape from a deep-seated environment.

### BAUXITE AND CLAY

A new estimate of the world's bauxite reserves and submarginal resources has been completed by S. H. Patterson, and a summary is published in Article 41. World reserves of bauxite are now estimated to be 5.7 billion tons, and additional submarginal resources are 8.7 billion tons. These figures, based on review of more than 200 published articles, are more than triple those presented by Fischer.[9] Vigorous exploration in the 10 years since then has resulted in many discoveries, especially the very large deposits now known on the Cape York Peninsula, Australia, and in the Republic of Guinea.

Reserves of bauxite in the United States are less than 1 percent of the world total; domestic ore would last only about 6 years, at the current rate of consumption, if foreign sources now meeting most of the requirements were cut off. The country is somewhat better provided with submarginal bauxite that could be utilized at costs higher than those currently prevailing.

#### Hawaii

In a report of a field study on aluminous deposits in Hawaii, S. H. Patterson (1–62) describes not only the bauxite, which is low-grade and ferruginous, but also saprolite. Most of the aluminum in the bauxite is in gibbsite; the saprolite also contains gibbsite, but its aluminum is mainly in halloysite. The saprolite contains nearly as much $Al_2O_3$ as the bauxite, but it contains less $Fe_2O_3$ and much more $SiO_2$ than the bauxite. The resources of low-grade bauxite on Kauai

[9] Fischer, E. C., 1953, Sources and reserves, chap. 3 of U.S. Bureau of Mines, Materials survey, Bauxite: 60 p.

are 110 million tons, West Maui 9 million tons, and East Maui 22 million tons. The average composition of deposits on Kauai is 4.7 percent $SiO_2$, 25.9 percent $Al_2O_3$, 39.4 percent $Fe_2O_3$, and 6.7 percent $TiO_2$. Deposits on West Maui are 7 percent $SiO_2$, 38 percent $Al_2O_3$, 22 percent $Fe_2O_3$, and 4 percent $TiO_2$; and on East Maui 6.6 percent $SiO_2$, 33.4 percent $Al_2O_3$, 31.4 percent $Fe_2O_3$, and 6.7 percent $TiO_2$. Resources of gibbsitic saprolite are estimated to be 500 million tons on Kauai, 200 million tons on West Maui, and 200 million tons on East Maui.

X-ray investigation of sieved fractions of samples from Kauai indicate that gibbsite tends to be concentrated in coarse sand and granule-size particles, but appreciable amounts are present in finer fractions. These results suggest that the bauxite could be upgraded by washing and screening, though the fine-grained gibbsite present in significant proportions could not be recovered in this way. The bauxite also has titanium, chiefly in titanomagnetite and anatase, which are most abundant in the silt- and clay-size fractions. Titanium would be difficult to concentrate, for it occurs in very fine grained minerals.

Plastic clay is associated with peat at 5 scattered localities on Kauai, but firing tests of 20 samples of these clays are unencouraging. The clays cracked and warped excessively and are unsuitable for ceramic products unless double fired or calcined.

#### New hypothesis for origin of Appalachian deposits

In a review of the bauxite deposits in the Valley and Ridge physiographic province, M. M. Knechtel (Art. 99) finds evidence for a new hypothesis of their origin. Many of these deposits are associated with thick accumulations of terra rossa consisting of argillaceous chert-bearing residual material produced by long-continued weathering of sedimentary formations of Paleozoic age that crop out extensively in this province. The gibbsite and kaolinite occurring in all the deposits are regarded by Knechtel as products of leaching whereby silica has been extracted from aluminous minerals present in bodies of terra rossa that became entrapped in sink holes at many places and at many different times since the close of the Paleozoic era. This concept is at variance with the views of writers who have suggested that all the bauxite deposits in the Valley and Ridge province and on the Atlantic Coastal Plain originated in early Tertiary time through leaching of finely divided crystalline debris transported by streams from outcrops of igneous and metamorphic rocks in the Blue Ridge and Piedmont provinces.

#### Derivation of clay in Washington

Field and laboratory studies by J. W. Hosterman of high-alumina clays in Spokane County, Wash., are yielding further information about the processes by which these clays developed. In particular, the Mica-Manito area has three different kinds of clay of three somewhat different origins. They include residual clays derived from pre-Tertiary metamorphic and granodioritic rocks, residual clay derived from Tertiary Columbia River Basalt, and transported clays of the Latah Formation, also of Tertiary age. The clay mineral derived from the metamorphic and granodioritic rocks is kaolinite ($Al_2O_3 \cdot 2SiO_2 \cdot 2H_2O$), and the clay mineral derived from basalt is endellite or hydrated halloysite ($Al_2O_3 \cdot 2SiO_2 \cdot 4H_2O$). Since the physical and chemical conditions under which all the rocks weathered during Tertiary time is the same, it seems that the mineralogic composition of the unweathered rock, especially the nature of its feldspars, must control the kind of clay formed. The unweathered metamorphic and grandodioritic rocks contain microcline and orthoclase, and fresh basalt contains plagioclase (labradorite). Thus it seems that, under the same weathering conditions, microcline and orthoclase have been converted to kaolinite, and labradorite has weathered to endellite. Unweathered feldspars found in the Latah Formation are microcline and orthoclase, and the clay mineral present is kaolinite; these circumstances point to a conclusion that the Latah Formation is derived from pre-Tertiary rocks.

### PHOSPHATE

Evidence is increasing that the phosphorite deposit in Beaufort County, N.C., is a major one, of very large tonnage. The potential importance of this deposit was first recognized by P. M. Brown [10] during a ground-water study by the U.S. Geological Survey. Brown's work is being continued by J. O. Kimrey (1–63) and J. B. Cathcart. The deposit has the drawback that it is overlain by 50 to 250 feet of overburden, which will present mining problems, yet exploration on the part of private interests is continuing.

The phosphorite, probably of middle Miocene age, was deposited in a basin cut into Eocene rocks on the flank of the Cape Fear arch. The northeast boundary of the deposit is where the phosphorite grades into clay with little or no phosphate; the clay grades into limestone. The phosphorite elsewhere is restricted by the basin edges and does not extend beyond the basin.

[10] Brown, Philip M., 1958, The relation of phosphorites to ground water in Beaufort County, N.C.: Econ. Geology, v. 53, no. 1, p. 85–101.

Field studies by J. B. Cathcart in northwest Arkansas on phosphate of Mississippian age indicate that small phosporite deposits, deposited in channels or low spots, are limited to an area centering in Searcy and Van Buren Counties. The deposits all seem to have been laid down in a bay at or close to the shoreline. The deposits are small and contain a maximum of about 22 percent $P_2O_5$, too little to be economic at the present time.

R. W. Swanson has compiled data for phosphate resources in the Phosphoria Formation (Permian) in central western Montana, north of Butte, in beds 3 feet or more thick down to a horizon that lies 100 feet below the lowest entry level. He estimates that there are 35, 65, and 80 million tons for grade cutoffs of 31, 24, and 18 percent $P_2O_5$, respectively. If depth is disregarded, the total phosphate resources in this area are many times as large.

In work on the Phosphoria in the northern part of the Snake River Range, M. H. Staatz and H. F. Albee have found a notable facies change in the principal phosphate horizon, the Meade Peak Phosphatic Shale Member of the Phosphoria Formation. In four measured sections along a strike distance of 10.5 miles in a single thrust block, the Meade Peak increases in thickness from 9.4 to 73 feet. This increase is a consequence of the location of the Snake River Range on the eastern edge of a miogeosyncline in the zone of greatest change during Permian time.

Phosphorite in the Indian Creek area of San Luis Obispo County, Calif., has been mapped and sampled by Howard D. Gower as the first stage of a study of phosphate in California. The phosphate forms small pellets that are mainly concentrated in beds 1 to 6 inches thick in the marine rocks of the Monterey Formation. The pelletal phosphate beds are interbedded with thin beds of porcellanite, diatomaceous mudstone, bentonite, and chert. Preliminary examination of the Foraminifera by Patsy J. Smith indicates that the phosphatic zone contains a shallow water fauna of middle Miocene age.

## EVAPORITES

Two major conferences on salt took place in the United States in 1962, and representatives of the U.S. Geological Survey participated in both of them.

One of these was the International Conference on Saline Deposits, convened in November 1962 under the auspices of the National Academy of Sciences and the American Geological Institute, in which a group of geologists from many parts of the world held a series of symposia on various subjects relating to the geology of salt, and also visited important deposits in Utah, Colorado, New Mexico, Mississippi, and Louisiana. During the course of the conferences, E. M. Shoemaker and D. P. Elston (1–63) described the structure and geologic history of the salt anticlines and their evaporite cores in the Paradox Basin, Colorado and Utah. C. L. Jones presented one paper (2–63) on the cyclic units of halite, anhydrite, and carbonate rocks of the Paradox region, and another (1–63) on similar cyclic units of southeast New Mexico, where later replacement processes gave rise to extensive deposits mined for potash. Papers on the Tatum salt dome, southeast Mississippi, which is the proposed site of experiments to ascertain the seismic effects of underground nuclear explosions, were presented by D. H. Eargle (1–63), who described the regional setting, and by J. Schlocker (1–63), who described the mineralogy of the vertically layered halite and anhydritic halite rock of the salt stock and also the mineralogy of the cavernous limestone and the anhydrite of the caprock.

Another salt conference, held at Cleveland, Ohio, May 1962, under the auspices of the Northern Ohio Geological Society, involved many phases of the technology of salt, as well as the geology of salt deposits, mainly those of marine origin. Ward C. Smith (1–63) reported on salt deposits in desert basins of the western United States.

### Death Valley, Calif., region

The Furnace Creek borate area, in the Death Valley region, California, has been the object of study by J. F. McAllister to clarify knowledge of the stratigraphic and structural setting of the productive colemanite-ulexite-probertite deposits, and thus to aid exploration for concealed deposits in the favorable zone of the Furnace Creek Formation. The borate area itself has been mapped in detail.

The age of the Furnace Creek Formation is considered Miocene or Pliocene, but on the basis of diatoms, K. E. Lohman is of the opinion that the age should be early and middle Pliocene. An incomplete, partly altered diatom assemblage from the uppermost part of the underlying Artist Drive Formation is early Pliocene in age; a similar assemblage from the lower part of the Furnace Creek Formation is also early Pliocene; and an abundant and well-preserved diatom assemblage in the uppermost part, above the borate deposits, is middle Pliocene. Unconformably above deformed Furnace Creek and Artist Drive are pumice beds of the Greenwater Volcanics, which thin to an edge under basaltic flows of the Funeral Formation in the Greenwater Range.

An outlying colemanite-ulexite-probertite deposit in the Resting Springs Range near Shoshone, Calif., 30 miles southeast of the Furnace Creek area, is in Tertiary sedimentary rocks under as much as 800 feet of pumice and welded tuff, which lapped over an irregular topography on Precambrian and Cambrian rocks. The older rocks here consist of the Stirling Quartzite, Wood Canyon Formation, Zabriskie Quartzite of Hazzard, 1937, Carrara Formation, and Bonanza King Formation. All of these units are thrust over the Konanza King along a southward-dipping surface that crosses the range.

## PEGMATITES

### Black Hills

A series of publications now being issued treat the pegmatites and regional geology of the southern Black Hills, S. Dak. (Kupfer, 1–63; Norton and others, 1–62; Norton and others;[11] Redden;[12] and Staatz and others[13]). This pegmatite area has been a major source of potash feldspar, mica, beryl, and lithium minerals.

The core of the Black Hills, which contains the pegmatites, consists entirely of Precambrian rocks. A thick sequence of metasedimentary rocks, together with a few bodies of metaigneous amphibolite, is intruded by the Harney Peak Granite and several thousand satellitic pegmatites. Schists nearest the granite carry sillimanite; farther away the highest grade mineral is staurolite, and still farther away is a garnet zone. Several sets of folds have been detected in the metasedimentary rocks, and large faults have been mapped.

The pegmatites, which are undeformed and unmetamorphosed, are divisible into three categories: 1) layered pegmatites, in which the most evident structure is layering caused by difference in texture and composition; 2) homogeneous pegmatites, consisting predominantly of quartz and feldspar with little change from one part of a pegmatite to another; and 3) zoned pegmatites. The name Harney Peak Granite is simply a general term applied to the larger bodies of layered pegmatites; no distinction between the lithology of the "granite" and the lithology of the pegmatites can be made. The zoned variety of pegmatite is the least abundant of the various kinds, but more than 100 of the zoned pegmatites of the southern Black Hills have been of economic value.

### North and South Carolina

Another pegmatite area that is an object of current work is in the Blue Ridge province of North Carolina, which has been the largest source of sheet mica in the United States. F. G. Lesure has been reexamining and compiling descriptive data for 1,350 mica mines and prospects. Nearly 100 mines have an individual production of more than 10,000 pounds of trimmed mica. More than half of the mines have an individual production of less than 500 pounds. About 30 percent of the mines contain reddish-brown (ruby) mica, 24 percent brown mica, and 34 percent green mica; the rest contain both ruby and green varieties. Two-thirds of the pegmatite bodies are tabular; a quarter of them are lenticular; and the rest are of irregular shape. About half of the bodies are discordant with the foliation of the enclosing metamorphic rocks. Zoning has been reported in 38 percent of the pegmatites, but zoning may have been overlooked in some of the others. More than half the deposits are deeply weathered, and for many of these the geology is incompletely known.

The Spruce Pine pegmatite district, North Carolina, is the most productive of the mica districts in the southeast. A new geologic map of an area of 225 square miles and a description of the general geology of the district have been published (Brobst, 1–62). The report also contains a discussion of the economic geology and a summary of the estimated resources of mica and other mineral commodities in the district.

W. C. Overstreet finds that spodumene has been noted 20 miles southwest of the supposed southwest end of the Kings Mountain spodumene district of North Carolina. A placer concentrate from alluvium in Thicketty Creek, 6 miles southwest of Gaffney, S.C., contains 0.5 percent spodumene.[14] This is positive evidence that a spodumene pegmatite is nearby.

## OTHER INDUSTRIAL MINERALS

Notable results have also been achieved in work on talc, alunite, barite, and zeolites.

Geologic mapping by H. M. Bannerman in the Richville and adjacent quadrangles, St. Lawrence County, N.Y., has led to the discovery and delineation of several tremolite-rich deposits somewhat similar to those now being mined for industrial talc.[15] The mode of

[11] Norton, J. J., and others, 1963, Geology and mineral deposits of some pegmatites in the southern Black Hills, South Dakota: U.S. Geol. Survey Prof. Paper 297–E. [In press]

[12] Redden, J. A., 1963, Geology and pegmatites of the Fourmile quadrangle, Black Hills, South Dakota: U.S. Geol. Survey Prof. Paper 297–D. [In press]

——— 1963, Diamond drill exploration of the Beecher No. 3–Black Diamond pegmatite, Custer County, South Dakota: U.S. Geol. Survey Bull. 1162–E. [In press].

[13] Staatz, M. H., Page, L. R., Norton, J. J., and Wilmarth, V. R., 1963, Exploration for beryllium at the Helen Beryl, Elkhorn, and Tin Mountain pegmatites, Custer County, South Dakota: U.S. Geol. Survey Prof. Paper 297–C. [In press]

[14] Hansen, L. A., and Theobald, P. K., Jr., 1955, Monazite placers of the Broad River and Thicketty Creek, Cherokee County, South Carolina: U.S. Atomic Energy Comm. RME 3126, 30 p.

[15] Bannerman, H. M., 1963, Map showing locations of deposits of tremolite potentially of value as a source of industrial talc: U.S. Geol Survey open-file map.

occurrence, mineralogy, and apparent size of the deposits suggest that some of them warrant systematic exploration and sampling. The deposits are mainly along the south side of the Oswegatchie River between Little Bow and Richville, N.Y., only a few miles from the industrial talc mining and milling centers of Fowler and Balmat. The larger and coarser grained deposits occur as discontinuous layers or lenses within a silicate-rich band of dolomitic marble of the Precambrian Grenville metasedimentary complex. In mineralogic composition, they grade from a matte of almost pure tremolite to relatively pure dolomite and to tremolitic quartzite. For the most part the strike is to the northeast and the dip to the southwest, but the rocks are complexly folded, and in this part of the area they are also sheared and brecciated.

#### Alunite in Wyoming

A hitherto undescribed alunite deposit at Aspen Mountain, Sweetwater County, Wyo., is reported by J. D. Love and P. D. Blackmon (1–62). Mineralogic analyses indicate that parts of the deposits have 60 to 90 percent alunite and may be potentially valuable for the preparation of commercial sulfates or aluminum refractory materials.

#### Barite in Arkansas

D. A. Brobst has applied a relatively simple turbidimetric field chemical test developed by Ward and others (1–63) to determine the barium content of rocks in the Caddo Gap and De Queen quadrangles, Arkansas. The method applies only for the concentration range of 500 to 10,000 ppm of barium, but it ordinarily is ample for prospecting; anything that contains more than 10,000 ppm of barium warrants examination by other techniques. This field chemical method has been tested at and away from known deposits of barite in the Stanley Shale of Mississippian age and the Trinity Formation of Cretaceous age. Samples determined to contain more than 10,000 ppm of barium by the chemical test were also checked by spectrographic techniques, which yielded results consistent with the results of the field tests. The background content of barium in these formations, as determined by the chemical test, is in the range of 500 to 1,000 ppm.

#### Barite in Nevada

Field studies by K. B. Ketner have clarified certain aspects of the geology of bedded barite deposits in the Shoshone Range, Nevada (Art. 11). Barite is interbedded with chert and lesser quantities of limestone in Paleozoic bedded chert units. Barite deposits are as much as 2,000 feet long, and several hundred feet thick. Barite units are monomineralic, occur in unaltered host rock, are related to bedded chert rather than to intrusives, and are nearly concordant to bedding. Nevertheless, they probably are epigenetic replacements of chert and limestone, because a discordance with bedding can be detected by mapping, barite veinlets are in the host rock, and fossils are baritized. Nevertheless, the barite deposits seem unrelated to neighboring sulfide deposits, which are normal mesothermal deposits in altered wall rocks, are related to intrusives, and are strongly discordant with bedding.

#### Zeolites in the Mojave Desert

R. A. Sheppard has begun a study in southeast California of zeolite-rich volcanic rocks of potential economic value. Reconnaissance of Miocene and Pliocene tuffaceous rocks in the Mojave Desert already has indicated the existence of large tonnages of clinoptilolite and notable quantities of other zeolites. Clinoptilolite, analcime, and erionite occur in predominantly monomineralic beds, which range from less than an inch to several feet in thickness. The zeolites are associated with unaltered glass and clay minerals (mainly montmorillonite), potash feldspar, and cristobalite of probable diagenetic origin.

## *RADIOACTIVE MINERALS*

#### Colorado Plateau

The identity of clay minerals in members of the Morrison Formation of the Colorado Plateau region aids in finding the source of the sediments, according to a study by W. D. Keller (1–62), but is not diagnostic of places favorable for the presence of uranium deposits.

A study by D. A. Jobin (1–62) of the transmissive capacity of sandstones and of the distribution of uranium deposits of the Colorado Plateau region suggested that (1) deposits are mainly in rocks of low to moderate regional transmissibility, (2) movement of uranium-bearing solutions and places of uranium deposition were controlled to varying degrees by the horizontal and vertical transmissibility of the rock, and (3) spatial relations of deposits to zones of high vertical transmissibility indicate control by major structures of probable early Tertiary age in conjunction with control by adjoining impermeable beds.

The unmineralized parts of the principal uranium-bearing sandstones of the Colorado Plateau region do not contain unusually large amounts of the elements commonly found in the ore deposits in those sandstones, according to a summary of the distribution of elements in sedimentary rocks of that region by W. L. Newman (1–62). The amount of potassium shows an inverse relation to the abundance of uranium deposits in different sandstones. The average vanadium content of the basal sandstones of the Chinle Formation, which contain relatively few vanadium-uranium deposits, is slightly greater than that of sandstones in the Salt Wash Member of the Morrison Formation, which are the principal host rocks for vanadium-uranium deposits.

Radiochemical analyses of ore and other rocks from the Ambrosia Lake, N. Mex., uranium deposits indicate that considerable radium ($Ra^{226}$) has migrated out of the ore and has been partly reconcentrated in barite, cryptomelane, and along the surfaces of mudstone bodies (H. C. Granger, Art. 17). This loss of $Ra^{226}$ should result in $Pb^{207}/Pb^{206}$ age determinations that are too great and $Pb^{206}/U^{238}$ age determinations that are too small. Corrections which allow for the effect that radium loss should have on the lead content of the ore suggest that total Pb/U ages should exceed 100 million years. This may mean that the Ambrosia Lake uranium deposits were formed before the host rocks of the Morrison Formation were deeply buried.

Granger and Santos (Art. 100) have described a cylindrical collapse structure in sandstone of the Morrison Formation near Ambrosia Lake, N. Mex., which provides the controls for a primary uranium ore body in an area in which most other deposits of the same age are controlled predominantly by sedimentary features. The collapse structure is interpreted to be a local control on mineralization from solutions moving laterally through the sediments, and not a conduit for solutions moving vertically from depth.

By using the ratio of the number of holes cutting ore to the total number drilled, W. B. Rogers and D. R. Shawe[16] estimate that the uranium-ore potential is 2 million tons in a 5-square-mile area which was explored mainly by widely spaced holes to obtain a geologic evaluation of part of the Slick Rock district, Colorado.

### Great Divide basin, Wyoming

As the result of detailed study of the schroeckingerite deposits in the Lost Creek area of the Great Divide basin in Wyoming, Sheridan and others (1–61) think that the uranium was deposited as schroeckingerite by the evaporation of ground water that derived the uranium from concealed deposits of higher grade. The concealed deposits may be along faults, or distributed in arenaceous clastic rocks through which the water has passed.

In the same region, studies by Pipiringos[17] and Masursky (1–62) give an integrated picture of the geologic setting of weakly uraniferous coals.

Lateral increase in uranium content of coal toward the external margin of the belt where coal accumulated, and enrichment in uranium at the top or at both top and bottom of different coal beds suggest that uranium was introduced epigenetically, possibly by downward percolating solutions and almost certainly by lateral migration for distances measurable in miles. Both authors agree that uranium in the coal is not the source of uranium in the schroeckingerite. Masursky suggests further that the uranium in the coal may be cogenetic with uranium in deposits in sandstone in the Crooks Gap area to the north.

### Texas coastal plain

Tuffaceous sedimentary rocks are considered to have been the source of uranium and associated molybdenum, phosphorus, and arsenic in uranium deposits of the Karnes area, Texas coastal plain, according to studies by A. D. Weeks and D. H. Eargle (1–63). Components of the tuffaceous sediments enclosing and lying above the deposits were highly reactive chemically, causing complex diagenetic alteration and the development of alkaline carbonate pore water. The uranium in the interstitial fluid was transported to a favorable depositional environment. As a result of detailed geologic and radiometric surveys, MacKallor and others (1–62) have suggested that this favorable environment was apparently provided in part by permeability traps and by reducing agents, associated with the Fashing-Edwards gas-distillate field, such as organic material, $H_2S$ and pyrite in the host rocks, or $H_2S$ originating in the Edwards Limestone.

The recent development of the Mabel New uranium mine, Live Oak County, Tex., on one of the radioactive anomalies of moderate intensity shown on the airborne radioactivity map of southeast Texas by Moxham and Eargle,[18] extends the area of economic deposits of the Karnes area 40 miles to the southwest and indicates that more deposits may be found in the areas of higher radioactivity in that region. The New mine, according to studies by D. H. Eargle, is in a sand in which economic deposits have not heretofore been found. The sand is tuffaceous and is believed to be of deltaic origin.

[16] Rogers, W. B., and Shawe, D. R., 1962, Exploration for uranium-vanadium deposits by U.S. Geological Survey, 1948–56, in western Disappointment Valley area, Slick Rock district, San Miguel County, Colorado: U.S. Geol. Survey Map MF–241, 3 sheets and text.

[17] Pipiringos, G. N., 1961, Uranium-bearing coal in the central part of the Great Divide Basin: U.S. Geol. Survey Bull. 1099–A, p. A1–A101, 5 pl., 34 fig.

[18] Moxham, R. M., and Eargle, D. H., 1961, Airborne radioactivity and geologic map of the Coastal Plain area, southeast Texas: U.S. Geol. Survey Geophys. Inv. Map GP–198.

### Uranium in Pennsylvania

In a summary of uranium occurrences in continental sedimentary rocks in Pennsylvania, Harry Klemic[19] points out that the exposures in which small deposits and occurrences in rocks of Devonian to Pennsylvanian age are known constitute only a small fraction of the area underlain by rocks potentially favorable for deposits.

### Phosphatic rocks in Florida

Reconnaissance studies by G. H. Espenshade (2–63) suggest that phosphatic sands and clays of Miocene and younger age are sufficiently widespread and abundant in parts of northern peninsular Florida to be of interest as potential resources of phosphate and uranium.

### Thorium and uranium, Front Range, Colo.

Igneous rocks having an abnormally high content of uranium and (or) thorium were intruded during Precambrian and Laramide times in the Front Range of Colorado. Thorium data obtained by George Phair on some 85 samples of the three major Precambrian intrusive rock types show that of these the Silver Plume types are the most notably enriched in thorium and range up to 106 ppm Th. The maximum enrichment within the Silver Plume is reached in the central part of the Front Range, an area later intruded by Laramide porphyries containing up to 300 ppm Th. An additional 55 thorium analyses and 50 new rapid rock analyses of the intrusives of central Colorado from areas other than the Front Range indicate a westward decrease in thorium content that is accompanied by a change in the character of the differentiation from more alkalic toward more calc alkalic types.

### Thorium in the Iron Hill complex, Colorado

Ground magnetic surveys of the Iron Hill alkaline complex, Gunnison County, Colo., by D. C. Hedlund, reveal strong magnetic anomalies, particularly along the north side of the complex, related to disseminations, aggregates, and dikelike bodies of magnetite, ilmenite, and perovskite in parts of the pyroxenite. Radiometric surveys by Hedlund and J. C. Olson indicate that some of the radioactivity anomalies coincide with the magnetic highs. This is apparently due to thorium substitution in perovskite which is intergrown with the magnetite and contains 0.12 to 0.15 percent $eThO_2$. Radiometric anomalies in the complex not attributable to perovskite are chiefly in carbonatite bodies, in which thorium is present in pyrochlore and other minerals.

### Monazite in North and South Carolina

W. C. Overstreet, J. L. Meuschke, and R. M. Moxham (4–62) have determined that zones of greater radioactivity observed in an airborne radioactivity survey of part of the Shelby quadrangle, North Carolina, coincide fairly well with areas underlain by rocks in which monazite is relatively abundant. Monazite placers in the valley bottoms were not disclosed by the radioactivity survey probably because the monazite is mostly near the base of the stream sediments and is buried by silt and fine sand containing little monazite.

W. C. Overstreet and others[20] report that the amount of thorium attributable to accessory monazite in rocks in the western piedmont of the Carolinas is twice as great in sillimanite schist and gneiss formed from shale as it is in biotite schist and gneiss formed from sandstone and graywacke. This relation is similar to the general distribution of thorium in shale and sandstone, but it is the reverse of the distribution of detrital heavy minerals in sedimentary rocks. The relation may be caused by the metamorphic crystallization of monazite in high-grade paraschists and paragneisses.[21]

### Uranium in coaly carbonaceous rocks

A systematic review of information about the occurrence of uranium in domestic coaly carbonaceous rocks by J. D. Vine[22] documents the evidence for a number of conclusions about uranium in coal. Among the more significant of these are: (1) most of the uranium is of epigenetic adventitious provenance, (2) original sorption of uranium by coaly carbonaceous rocks was effected by an ion-exchange process, (3) presence of uranium in coaly rocks is related to its availability in solution rather than to effectiveness of a mechanism of precipitation, (4) marked local differences in uranium content are not clearly related to differences in composition of coal, and (5) uraniferous coaly rocks of the Fort Union lignite region are of relatively great importance as resources of uranium.

[19] Klemic, Harry, 1962, Uranium occurrence in sedimentary rocks in Pennsylvania: U.S. Geol. Survey Bull. 1107–D, p. 243–287.

[20] Overstreet, W. C., Yates, R. G., and Griffitts, W. R., 1963, Heavy accessory minerals in the saprolite of crystalline rocks in the Shelby quadrangle, North Carolina: U.S. Geol. Survey Bull. 1162–F. [In press]

[21] Overstreet, W. C., 1960, Metamorphic grade and the abundance of $ThO_2$ in monazite: Art. 27 *in* U.S. Geol. Survey Prof. Paper 400–B, p. B55–B57.

[22] Vine, J. D., 1962, Geology of uranium in coaly carbonaceous rocks: U.S. Geol. Survey Prof. Paper 356–D, p. 113–170.

#### Alteration in relation to uranium ore

Studies by K. G. Bell have shown that most, if not all, uranium deposits in terrestrial sedimentary rocks are within or on the margins of large masses of rock that have been altered and leached by apparently warm aqueous subsurface solutions. It seems, therefore, that parts of the host formations and nearby formations may have provided the uranium and other metals in the deposits. Accordingly, the deposits resulted mainly from intraformational leaching and redistribution of metals by aqueous subsurface solutions.

## MINOR ELEMENTS

The yttrium silicate thalenite was identified in rocks from a pegmatite in Colorado. This mineral was known to occur in several Scandinavian pegmatites, but had been reported previously from only one other locality in the United States. A study of the mineral by J. W. Adams, F. A. Hildebrand, and R. G. Havens (1–62) showed that the Colorado thalenite has a lanthanide distribution somewhat different from that found in Swedish thalenite.

Raymond L. Parker and Raymond G. Havens have reported the occurrence of thortveitite, a rare scandium-yttrium silicate, associated with fluorite at the Crystal Mountain mine near Darby, Mont. (Art. 2). This is the first occurrence of thortveitite to be reported in the Western Hemisphere and is a new mode of occurrence for the mineral, which was previously found only in granite pegmatites.

A rare sodium niobate mineral (igdloite or lueshite) associated with vermiculite in altered mafic alkalic rock was discovered during 1962 by R. L. Parker, J. W. Adams, and F. A. Hildebrand at Gem Park, near Hillside, Colo. (1–62). The physical properties and X-ray powder data are similar to those of minerals reported only from Greenland and the Republic of the Congo. The mineral contains mostly sodium and niobium with minor calcium, titanium, rare earths, and possibly thorium.

Mafic alkalic rocks which comprise the intrusive complex at Gem Park are cut by abundant carbonatite dikes. These dikes contain the rare-earth minerals ancylite and bastnaesite, rare-earth-bearing apatite, and unidentified niobium and thorium minerals.

J. W. Adams and F. A. Hildebrand have found that carbonate rock from the dump of the Yellow Jacket mine, Lemhi County, Idaho, contains the rare-earth minerals synchisite and xenotime.

A thallium-rich mineral, associated with realgar and orpiment, from the Getchell gold mine in north-central Nevada has been discovered by G. J. Neuerburg. X-ray data suggest that the mineral is a thallian mercurian tennantite.

E. J. Young has found evidence in support of Taborsky's conclusion that fluorapatites have higher Ce-earth:Y-earth ratios than chlorapatites. The ratios are presumed to be higher in apatites from salic rocks than in those from mafic rocks because of higher F:Cl ratios in apatites from salic rocks.

George Phair reports that 90 percent of the niobium in gabbros from the southern California batholith is in iron ores. Through the differentiation sequence from tonalite to granite, biotite and hornblende are increasingly niobium rich, but inasmuch as these minerals decrease in abundance through the sequence, their niobium contributions to the total rock do not vary greatly.

Research on the occurrence of minor elements in coal, by Peter Zubovic, Taisia Stadnichenko, and N. B. Sheffey, has shown that coal in the northern Great Plains and Rocky Mountain provinces is rich in boron; coal in the eastern interior region is rich in vanadium, chromium, and germanium. Some coal in Indiana and eastern Kentucky is rich in beryllium (p. A62). The partitioning of elements between organic and inorganic fractions of coal is partly controlled by depositional environment. An organic affinity series of the elements can be used to predict their distribution in carbonaceous sediments.

#### Distribution of vanadium in Paleozoic rocks of the West

J. D. Vine has found that vanadiferous black shales occur in western conterminous United States in rocks of every Paleozoic system from Cambrian through Permian, in a wide variety of geologic environments. The principal vanadiferous shale deposits of Ordovician, Silurian, and Devonian ages known thus far are in eugeosynclinal strata or in rocks that are transitional between eugeosynclinal and miogeosynclinal strata in central Nevada. The early Paleozoic strata in central Nevada were involved in orogenic movements in latest Devonian and early Mississippian time and were subjected to erosion during later Paleozoic time. Accordingly, the widespread deposits of black shale in Mississippian and later Paleozoic time were probably derived in large part from the erosion of earlier Paleozoic rocks. The younger black-shale deposits spread far to the east, yet for the most part they were separated by nondetrital rocks from a source of sediment on the craton. Vanadiferous black-shale deposits in the later Paleozoic include strata in the following formations: the Milligen Formation in Idaho; the Chainman, Diamond Peak, and Tonka Formations of Dott in Nevada and western Utah; the Deseret, Great Blue, and Manning Canyon Formations in central Utah; and the Phosphoria Formation in Wyoming and southeastern Idaho. Metal-rich shale also occurs in the Heath Formation in Montana and the Minnelusa Sandstone in South Dakota.

Robert Mays has found that phenacite collected in the Mount Wheeler mine area, in the Wheeler Peak quadrangle, White Pine County, Nev., contains 200–600 ppm boron and 100–150 ppm germanium. Though it is not uncommon for phenacite to contain boron, none previously reported contains as much as 200 ppm boron.

## ORGANIC FUELS

The economy of the United States is powered largely by energy derived from the fossil fuels—coal, oil, and natural gas. Efficient development of the Nation's energy supplies to meet rapidly increasing needs, and planning for the future economic development of supplemental sources such as nuclear energy require a careful analysis of the supplies, costs, and uses of the fossil fuels. A study group of the U.S. Department of the Interior Energy Policy Staff (1–63), which includes V. E. McKelvey and D. C. Duncan of the U.S. Geological Survey, considers that known minable reserves of fossil fuels will constitute an adequate supply for the next few decades, and that gains in technology will enable the Nation to utilize some part of the vast potential resources that are now too costly to mine, at costs comparable to those now prevailing. The Energy Policy Staff expects that if needed research is undertaken to further advance fossil fuel technology, supplies can be developed adequate for another century or more, even at the much increased rates of consumption anticipated. In the long run the life of our fossil fuel resources is clearly limited, and the study points to the need to acquire more information on marginal and submarginal deposits.

Some of the more significant results of recent U.S. Geological Survey investigations of organic fuels are summarized here.

### PETROLEUM AND NATURAL GAS

#### Oil and gas map of the United States

A map showing oil and gas fields of the United States at a scale of 1:2,500,000 has been prepared by Sophie D. Vlissides. The map is a revised version of the earlier oil and gas maps of the United States, the last edition of which was published in 1955. The current map will not show the pipelines that were on previous editions, because the rapid expansion in pipelines makes them difficult to show at the map scale and reduces the period of usefulness of the map.

#### Oil and gas potential in specific areas

Extreme depositional thinning and local truncation of beds beneath Cretaceous unconformities in the area around Lamont, Wyo., have been demonstrated by A. D. Zapp and W. A. Cobban (1–62). Their findings are the result of extensive studies of marine and nonmarine sedimentary facies in Upper Cretaceous rocks and are supported by faunal evidence. More than 4,000 feet of strata, including the Mesaverde Formation and equivalent rocks which are productive of oil and gas in the Great Divide basin to the west, is locally absent in the Lamont area where the Lewis Shale lies directly on the Cody Shale in depositional contact.

W. B. Cashion reports that study of the overall success ratio of wells drilled for oil and gas in Tertiary strata in the Uinta basin of Utah indicates that the most promising strata are in the Green River and Wasatch Formations in the area between the structural axis of the basin on the north and the depositional axis on the south.

A zone of intensely deformed rocks mapped by R. L. Miller (1–62) in the Big Stone Gap quadrangle, in westernmost Virginia, indicates that the Pine Mountain fault, which underlies the Cumberland overthrust block, comes to or nearly to the surface in the northwest part of the quadrangle. This interpretation suggests the probable presence of a major anticline beneath the Powell River valley and affords an excellent opportunity to test oil and gas potential of the pre-Devonian rocks in this area by shallow drilling.

Preliminary studies by M. C. Israelsky of Foraminifera from beds near the Nacimiento River in the Jolon quadrangle, Monterey County, Calif., indicate that the beds, which were formerly considered to be Cretaceous in age, are no older than Paleocene. According to D. L. Durham, who has mapped this quadrangle, the discovery is significant in that it enlarges the known extent of an oil-bearing basin of Tertiary age.

#### Distribution and configuration of basement rocks in California

A map of California has been prepared showing the exposed basement rocks and the configuration of the top of basement rocks in parts of sedimentary basins. The map, which was compiled by Merritt B. Smith, illustrates the concentration of oil and gas fields in moderately deep parts of the basins and a close association of the fields with arches in the basement surface.

## OIL SHALE

On the basis of surface and subsurface studies, and of assays by the U.S. Bureau of Mines of numerous cores and samples from trona, oil, and gas test holes, W. C. Culbertson estimates that oil shale in the Green River Formation in the Green River basin of Wyoming has a potential oil yield of 239 billion barrels in beds more than 15 feet thick that yield more than 10 gallons of oil per ton. Included in this total is about 27 billion barrels of oil, of which 20 billion is in the Tipton Shale Member, in higher grade beds that yield more than 25 gallons per ton.

R. L. Rioux has reported 16 feet of oil shale in the lower part of the middle tongue of the Green River Formation in the LaBarge 1 SW quadrangle, Sublette County, Wyoming. These beds, which have an average assay from surface samples of 18 gallons of oil per ton, are apparently limited to the area east of the Green River. Field relations suggest the possibility that thicker deposits are present east and northeast of the quadrangle, an area which has hitherto been considered barren of oil shale.

In the Grand Mesa area, Colorado, core representing only the lowermost 2 feet of the Mahogany bed of the Green River Formation was collected for assay from the Collbran Road core hole. The cored sample shows an average oil content of 50 gallons of oil per ton. The total Mahogany bed, which is 3 to 4 feet thick, underlies an area of about 200 square miles on Grand Mesa. When this rich zone is combined with underlying beds it totals 16 feet of oil shale that will yield an average of more than 18 gallons of oil per ton. A similar thickness of uncored beds above the Mahogany bed is estimated to be of equal grade. According to J. R. Donnell, the oil shale underlying Grand Mesa will add an additional 2 billion barrels of oil to the previously estimated reserves of the Piceance Creek basin.

In a study of the distribution of organic material in the Chattanooga Shale, Andrew Brown and I. H. Breger have determined that the distribution of the organic components has a direct relation to the distance from the shoreline of the ancestral Chattanooga sea. The organic material, which ranges from 17 to 25 percent of the black shale of the Chattanooga, is composed of sapropelic and humic fractions. Although the percentages of these fractions are not in themselves readily measurable, they can be obtained from the hydrogen content, which represents the sapropelic fraction, and the tar-acid content, which represents the humic fraction. The hydrogen content increases with remarkable consistency away from the shoreline, while the tar-acid content decreases in the same direction but with less consistency (Breger and Brown, 1–62). The hydrogen content also shows a good correlation with the oil yield; in Walden Ridge, Tenn., and northern Alabama, close to the shoreline, the hydrogen content is about 4 percent and the oil yield 2 to 3 gallons per ton. In the central and northern part of the Eastern Highland Rim, nearer to the center of the ancestral Chattanooga sea, the hydrogen content is 5 to 7 percent and the oil yield is 9 to 10 gallons per ton.

## COAL

### Eastern Kentucky

In a recently published report, J. W. Huddle, E. J. Lyons, H. L. Smith, and J. C. Ferm (1–63) estimate that the coal reserves of eastern Kentucky total about 33 billion tons in beds more than 14 inches thick, including 20 billion tons in beds more than 28 inches thick. The comprehensive report, which was prepared in cooperation with the Kentucky Geological Survey and the U.S. Bureau of Mines, is the product of a long-term program of work on coal in eastern Kentucky and includes data from many investigations of smaller areas. Several of these were also published as separate reports during the fiscal year (Bergin, M. J., 1–62; Englund, K. J., and others, 1–63; Patterson, S. H., and Hosterman, J. W., 2–62). Additional information on eastern Kentucky coal may be obtained from the several maps in the Geologic Quadrangle Series on this region which have been published through the year. On these maps the coal beds are delineated and their thicknesses are generally included in a brief text.

### Pennsylvania

Recent reports on the eastern Pennsylvania anthracite district demonstrate the effect of complex structure on the mining of coal and show the probable correlation of coal beds across faults and folds. One of these publications, a map by Walter Danilchik and others (1–62), covers part of the Western Middle anthracite field, and another, by G. H. Wood and others (1–62), describes part of the Southern anthracite field. These publications give the thickness of the important coal beds and show their extent by means of maps and cross sections.

### Ohio

A study of the geology and coal resources of Belmont County indicates remaining coal reserves of 4.8 billion tons distributed in 7 beds of high-volatile A and high-volatile B bituminous rank. Included in the estimate is 3.4 billion tons in the commercially mined

Pittsburgh and Sewickley coal beds. Data on thickness and areal distribution of the coal beds and on stratigraphy and sedimentation of the Upper Pennsylvanian and Lower Permian coal-bearing rocks are also included in a report prepared by H. L. Berryhill, Jr.[23]

### New Mexico

Field investigations preliminary to detailed mapping in the Western Raton coal field have led to the discovery of a potentially commercial coal zone about 8 miles southeast of Vermejo Park, N. Mex. According to C. L. Pillmore, the coal zone is about 15 feet thick in the valley walls of the Vermejo River and is composed primarily of coal beds less than 2 feet thick in the lower part and a bed more than 5 feet thick in the upper part. This thicker bed splits into two thinner beds a short distance upriver; however, the lateral extent of this zone and the thickness of the coal beds beneath the ridges adjacent to the river are not known.

### Utah

C. H. Carpenter and L. J. Bjorklund report that coal was discovered in two test holes drilled during a ground-water investigation of the Upper Sevier River valley, Utah (see p. A39). In a hole in the SE¼ sec. 33, T. 33 S., R. 2 W., a coal bed 20 feet thick was penetrated between 420 and 440 feet, and thin coal beds were found between 440 and 470, and 480 and 485 feet. In the SW¼ sec. 29, T. 34 S., R. 2 W., beds of coal 1 to 3 feet thick were penetrated between 354 and 474 feet.

### Wyoming

Harold Mazursky, in a report on uranium-bearing coal in the Great Divide Basin of Wyoming (Mazursky, 1–62), has estimated reserves of nine principal coal beds, which range in thickness from a few inches to 42 feet and average about 7 feet. The area, which includes about 300 square miles in the eastern part of the Red Desert area in Sweetwater County, Wyo., contains about 2,000 million tons of measured and indicated reserves of subbituminous coal. The study indicates that the large reserves of coal are of interest primarily as fuel and that uranium probably could be produced only as a byproduct.

Geologic mapping in the northern part of the Laramie basin, Wyoming, by H. J. Hyden has shown that the younger coal beds mined in the area are in the Medicine Bow Formation of Late Cretaceous age, rather than the Hanna Formation of Eocene age as previously reported. The Medicine Bow Formation is extremely thin in this part of the Laramie basin; it ranges from 0 to about 400 feet in thickness as compared with more than 4,000 feet in the adjacent Carbon basin and more than 6,000 feet reported in the Hanna basin.

### Washington

Geologic mapping in the western foothills of the Cascade Range near Seattle, Wash., by J. D. Vine and H. D. Gower has made possible the subdivision of a sequence of Eocene strata about 14,000 feet thick into four formations. The lower formation contains marine fossils and may constitute a potential source of oil. The three upper formations assigned to the Puget Group are nonmarine and include a middle one that is largely composed of volcanic debris. The other two contain sandstone and coal. Fossil leaves studied by J. A. Wolfe are the basis for correlating these strata with arkosic sandstone and coal in the Puget Group, which is about 6,200 feet thick in the Green River area to the south. Coal reserves in the Puget Group in the area studied are estimated to be 630 million tons, about three-quarters of which is of bituminous rank. Total coal resources are much greater and may be as much as 5 billion tons.

### Alaska

Coal-bearing rocks of Tertiary age underlie a lowland area of at least 5,000 square miles at the head of Cook Inlet, between the Susitna River and the Alaska Range. Field studies by F. F. Barnes have shown that potentially valuable coal deposits, with a few minor exceptions, are confined to an area of less than 500 square miles in the southern part of the region. This area contains a large but undetermined number of beds of lignite and subbituminous coal of minable thickness, including at least two 30- to 50-foot beds, which were traced for several miles.

## WATER RESOURCES

The U.S. Geological Survey investigates the occurrence, availability, and quality of surface and underground waters and the sediment discharge of streams. An extensive hydrologic network of stream-gaging stations, observation wells, and water-quality sampling stations throughout the country provides continuing basic data. Compilations of these basic data are published in the following U. S. Geological Survey Water-Supply Paper series:

"Surface Water Supply of the United States"
"Ground-Water Levels in the United States"
"Quality of Surface Water of the United States."

[23] Berryhill, H. L., Jr., 1963, Geology and coal resources of Belmont County, Ohio: U.S. Geol. Survey Prof. Paper 380. [In press.]

The first two are published at 5-year intervals and the last is published annually. In addition, nationwide reports which describe flood frequency at selected gaging stations and extend the data to ungaged sites on major and minor streams are being published in the Water-Supply Paper series in several parts that correspond to the drainage-basin subdivisions of "Surface Water Supply of the United States."

Areal investigations of water resources are made largely in cooperation with State, local, or other Federal agencies listed on page A247. These studies include the various aspects of the geologic and hydrologic environment that relate to the occurrence and movement of water on the surface and underground. Such studies of water resources stress evaluation of sources of supply, chemical and physical composition, computation of the quantity available for use, description of the direction and rate of movement, evaluation of fluctuations in flow, and determination of disposition of the supply as use, waste, or outflow.

Diversified water-resources investigations are in progress in nearly every State. These fall into two general categories, "area" and "systems" studies. Area studies cover investigations of specific hydrologic problems within an area, generally comprising a political subdivision—the problems of a municipality, a county, or a State. Systems studies, on the other hand, are investigations of the hydrologic environment of natural units such as a river basin or isolated valley, whose area may include a number of political subdivisions. The purpose of these investigations is to determine the effect on the hydrologic system of changes in any part of it; for example, to predict how use of ground water in one municipality may influence stream flow in another part of a river system. Four systems studies were begun in 1963 and several more are under consideration.

Investigations stressing the economic aspects of water as a resource are treated in the following section under four areas (fig. 1), which correspond to the administrative subdivisions of the Water Resources Division (p. A254).

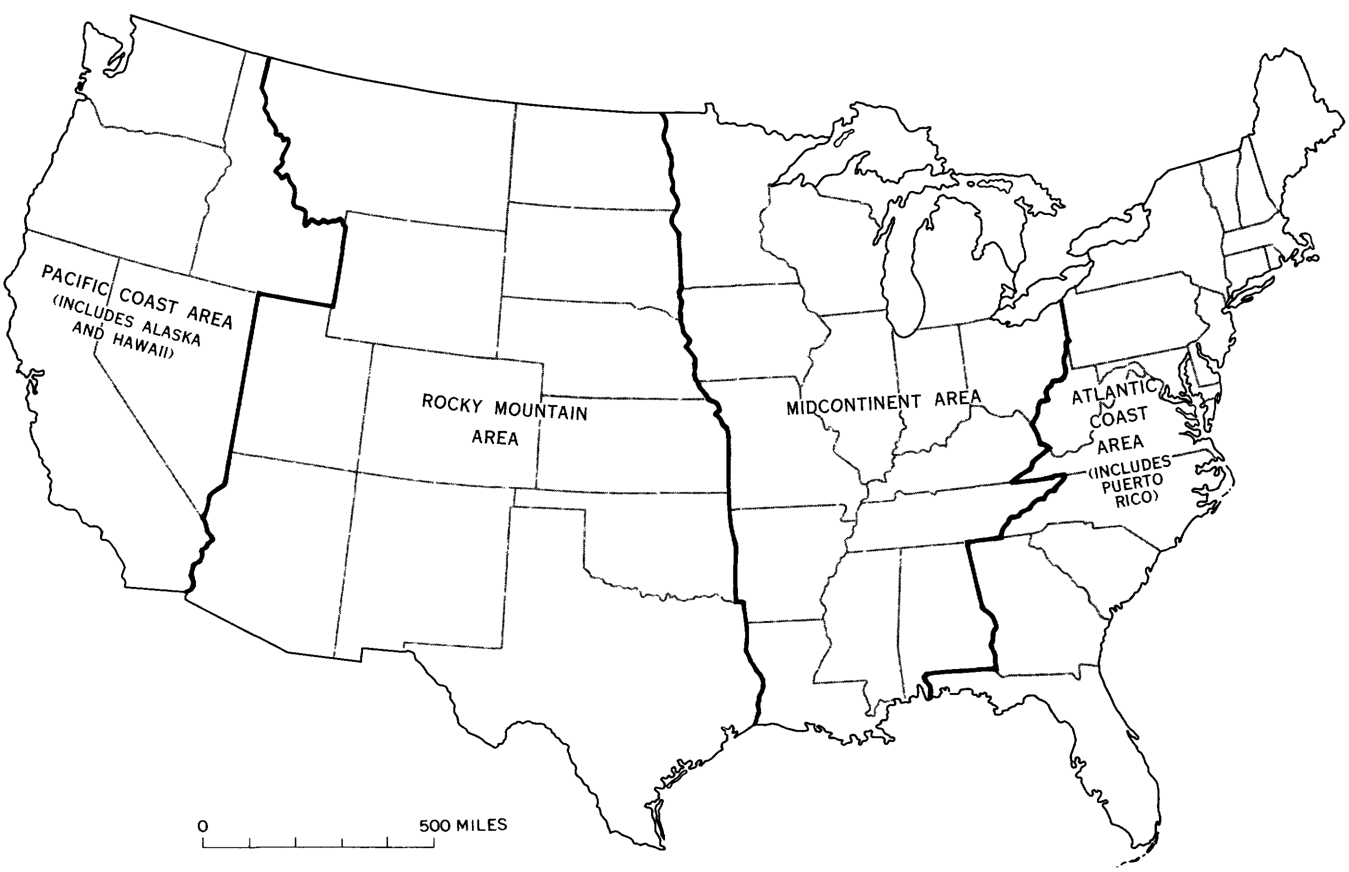


FIGURE 1.—Index map of the United States, showing areal subdivisions used in discussion of water resources.

## WATER USE

Development and use of water have been expanding rapidly in the United States in recent years and will continue to expand in conformity with population and economic growth. Population growth alone will require large increases in domestic and municipal water supplies, but superimposed on this trend is a marked per capita increase in water use in the home and an even more striking increase in water use by industry. The average per capita use for public water supply, which includes water for fire protection, street flushing, and business establishments, grew from 145 gpd (gallons per day) in 1950 to 153 gpd in 1960. Intake of water by six principal water-using industries increased more than 60 percent from 1952 to 1962.

To meet the increasing demand for information for water planning, the U.S. Geological Survey investigates and prepares reports on water use by specific industries, metropolitan areas, States, and by the Nation.

### Ground-water conditions in the Nation

A comprehensive summary of the national water situation, with emphasis on ground water, has been published.[24] The 1,121-page report is based on reports from the field summarizing conditions as of early 1961, but certain critical information is up to date as of the summer of 1962.

Second in a series of 10-year summaries of the national ground-water situation the report discusses national water problems and needs, largely on the basis of the 1961 report of the Senate Select Committee on National Water Resources and its supporting documents. Tables drawn from the committee's report show, for each of 22 water-resource regions in the conterminous United States, the 1954 demand for water for "withdrawal" uses (public supply; rural domestic and stock; industrial, excluding hydropower; and irrigation), the amount used consumptively (evaporated, or incorporated in a product), the remaining streamflow, and the aggregate storage capacity of surface reservoirs. Similar figures, plus amounts of streamflow needed for pollution abatement, are given for 1980 and 2000 as forecast by the committee.

The bulk of the current report consists of individual sections describing conditions in the 50 States, the District of Columbia, Puerto Rico, the Virgin Islands, Guam, and American Samoa. Climate and runoff, geology and occurrence of ground water, use of fresh and saline water, and existing and potential water problems are summarized. Future prospects for increased demand and for developing water to meet it are discussed.

[24] McGuinness, C. L., 1963, The role of ground water in the national water situation: U.S. Geol. Survey Water-Supply Paper 1800, 1,121 p.

### Public water supplies of the 100 largest cities in the United States, 1962

C. N. Durfor and Edith Becker have completed a compilation of the public water supplies of the 100 largest cities in the United States (1960 U.S. Census), which provide 9,650 mgd (million gallons of water per day) for 60 million people, 34 percent of the Nation's population. A descriptive inventory itemizes adjacent communities supplied by each city, population of each city, total population served, sources of supply (including auxiliary and emergency supplies), average amount of water used daily, lowest 30-day mean streamflow during recent years, type of water treatment, rated capacity of each treatment plant, and storage capacity for raw and finished water. Maps show the water sources, treatment plants, and areas served by the 58 water systems. Chemical, spectrographic, and radiochemical analyses of treated water, and chemical and spectrographic analyses for many of the raw-water supplies are presented in tabular form.

Twenty-one of the 100 largest cities use groundwater exclusively for public supplies, and 9 cities use a combination of ground and surface water. Sixty-nine cities use water directly from streams or from reservoirs that impound stream water; of these cities, 37 depend solely upon impounded waters and 20 depend solely upon natural streamflow. Water from the Great Lakes furnishes part or all of the water supply for 10 of these largest cities.

Chemical analyses of treated water supplies indicate that more than 90 percent of the supplies contain less than (a) 500 ppm (parts per million) of dissolved solids, (b) 100 ppm of sulfate, (c) 50 ppm calcium, sodium, and chloride, (d) 30 ppm of silica, (e) 20 ppm of magnesium, (f) 5 ppm of potassium and nitrate, and (g) 1 ppm of fluoride.

### Report on water resources of Alabama

The water resources of Alabama are described by Swindel, Williams, and Geurin (1–63) in the first of a series of popular-style summary reports on the water resources of selected States. Rural residents in Alabama require an average of 20 gpd of water per person, and the total rural demand is about 50 mgd, of which about 30 mgd is for domestic use and about 20 mgd for stock. Municipal water supplies serving 5,000 people or more are listed by the name of the community; the estimated number of people served; and the sources of water, such as springs, wells, or streams. These municipal systems withdraw about 190 mgd to supply a population of about 1.7 million, indicating a per capita use of about 110 gpd. An estimated 5,000 mgd is withdrawn for industrial use, including water used only for cooling.

#### Water requirements, Marquette iron district, Michigan

J. H. Butler reports that water may prove to be a controlling factor in the development of the low-grade iron ores on the Marquette iron range of Michigan. The change from underground mining of standard iron ores to open-pit mining and the concentration and pelletizing of low-grade iron ores involves an increase in the amount of water withdrawn and consumed, and creates a problem in the disposal of sediment-loaded effluent from tailings basins. In order to assist those concerned with water management on the Marquette iron range, mathematical models of the new processes are being developed to evaluate costs of water supply and disposal under variations in process design.

#### Use of water in Springfield, Mass.

In 1957 the public water systems in the Springfield, Mass., urban area described by J. C. Kammerer and H. C. Baldwin (1–62) supplied an average of 97.9 mgd; an estimated 96.5 mgd was obtained from surface-water supplies and 1.4 mgd from ground water. In the same area, self-supplied industrial water users diverted an average of 320 mgd from surface-water supplies and pumped 7 mgd from ground water.

#### Use of water in Green Bay, Wis., area

According to Doyle B. Knowles, Frederick C. Dreher, and George W. Whetstone, nearly 500 mgd of water was used daily in 1959 in the highly industrialized Green Bay, Wis., area, of which about 98 percent was surface water from Green Bay, Lake Michigan, and Fox River, and about 2 percent was ground water. It is estimated that with proper spacing and development of wells, the ground-water supply from the sandstone aquifer could be increased from 5.4 mgd to as much as 30 mgd.

#### Use of water in Flint, Mich., area

An average of 45 mgd of water was withdrawn for use in Genesee County, Mich., in 1958 to serve a population of 340,000. According to S. W. Wiitala, K. E. Vanlier, and R. A. Krieger,[25] about 81 percent of this water, or 36 mgd, was withdrawn from the Flint River by the Flint public water system. The rest was supplied by wells. Industry used nearly half of the water supplied by the Flint public supply and this constituted about 98½ percent of all water used by industry in the county. For 1958 conditions, it was estimated that at least 30 mgd of river water is needed for waste dilution in the Flint River during warm weather.

[25] Wiitala, S. W., Vanlier, K. E., and Krieger, R. A., 1963, Water resources of the Flint area, Michigan: U.S. Geol. Survey Water-Supply Paper 1499–E. [In press]

#### State water-resources investigations folders

A series of 8 by 10½-inch folders entitled "Water Resources Investigations in [State]" was prepared in 1963 to inform the public about the current water-resources program in each of the 50 States and Puerto Rico. Each State folder has a large map that shows the location of stream-gaging stations, ground-water observation wells, quality-of-water sample-collection sites, and areal hydrologic studies. Smaller maps show average annual runoff, availability of ground water, discharge of principal streams, and average concentration of dissolved solids in streams. A brief text lists the hydrologic network, the areal and Statewide projects, and selected references.

## ATLANTIC COAST AREA

Water is plentifully available throughout most of the Atlantic coast area. Water-deficient areas are few. The problems, therefore, concern the water environments and our disturbance of them, and the need for prudence in developing and managing the water resources. Specifically, the problems are associated with the following water features:

(1) Natural quality of the water. Natural fluctuations in mineral constituents and physical properties, including normal sediment discharge and natural contamination.

(2) Detrimental effects on quantity and quality due to utilization of the water or changes in its physical environment, including pollution, invasion of freshwater bodies by saline water, hydrologic effects of urbanization and other land-use practices, and local competition for water supplies.

(3) Seasonal variations in supply; excess supply (floods, wetlands) at times and temporary deficiencies in supply (low streamflow, low ground-water storage) at other times.

(4) Geographic disharmony of supply and demand. Locally, population and industrial growth exceed readily available supplies, and water must be imported from distant sources.

A great range in topographic and geologic environments gives rise to great variation in hydrologic conditions in the Atlantic coast area. The regional water environments include the mountainous Appalachian province, the rolling Piedmont province, and the low-lying Atlantic Coastal Plain. Surface-water supplies are more readily developed in the Appalachian and Piedmont provinces; ground-water supplies are most practicable in the Atlantic Coastal Plain province. Some serious hydrologic problems are associated with the maritime environment of the coastal plain. In addition, the coastal plain is experiencing urbanization at a faster rate than the other provinces and includes the sprawling "megalopolis" extending from Virginia to New England.

The objectives of the water studies summarized below are to describe the water resources of the area and to provide interpretive hydrologic analyses needed by those responsible for management of these resources. Owing to the variety of water environments and water problems in the Atlantic coast area, the water studies are quite varied.

## NEW ENGLAND

### Ground-water supplies and quality in Maine

In southwestern Maine, G. C. Prescott, Jr., reports that wells in the igneous and metamorphic bedrock formations are generally less than 250 feet deep. The yield ranges from 10 gph (gallons per hour) to 150 gpm (gallons per minute). The average yield is 11 gpm and the median yield is 6.5 gpm; 86 percent of the bedrock wells obtain 3 gpm or more.

Water in bedrock is more highly mineralized than water in most unconsolidated materials. The average hardness of water from bedrock formations is 79 ppm (moderately hard). Water from glacial outwash deposits averages the lowest in hardness (16 ppm) and in chloride (5 ppm), and water from bedrock is highest (79 ppm and 21 ppm, respectively). Water from unconsolidated formations is generally acid (average pH, 6.5), whereas most water from bedrock wells is alkaline (average pH, 7.5).

### Sources of ground water in New Hampshire

Preliminary findings in a ground-water investigation of the Lower Merrimack River valley by J. M. Weigle indicate that a possible sustained yield of 15 mgd is available in a 90-square-mile area. The major source of this supply is small deposits of stratified glacial sand and gravel in valleys tributary to the Merrimack. Individual gravel-packed wells in some of those deposits yield more than 400 gpm.

Lacustrine varved clay and silt occur at several places in this part of the Merrimack River valley; the deposits appear to be unconnected, and evidently were laid down in several small bodies of water rather than a single large lake.

According to Edward Bradley, small but usually reliable supplies of ground water, sufficient for household and rural use, are generally available from the bedrock at most places throughout southeastern New Hampshire. Larger supplies can be obtained in many places from unconsolidated glacial outwash and ice-contact deposits, particularly where these deposits are situated favorably with respect to inducing recharge from nearby streams, ponds, or lakes.

### Availability and quality of water supplies in Massachusetts

Studies in several river basins in the coastal region of northeastern Massachusetts lead E. A. Sammel to conclude that swamp deposits, which pond and store large quantities of water, nevertheless may retard recharge to underlying ground-water bodies, and at times may act as semiconfining layer for underlying deposits.

Sammel found that large increases in the use of water are feasible in the Ipswich River basin. In 1960, the average use of water was about 10 mgd, of which nearly 4½ mgd was ground water. He estimates that as much as 60 mgd of ground water is available in the basin. Chemical quality of both ground and surface water is generally good; ground water from bedrock and that from unconsolidated deposits is comparable in quality.

As part of a water management study of the Assabet River basin, W. N. Palmquist and S. J. Pollock estimate that permeable unconsolidated deposits underlying the Town of Acton may contain more than 3 billion gallons of water. They estimate that the least possible effective recharge would be about 4 inches annually or 3.8 mgd, and they conclude that this ground-water reservoir, if development proves feasible, is more than adequate to satisfy the foreseeable demands in the Town of Acton.

Studies by John A. Baker show that the abandoned valley of the preglacial Merrimack River is a potential source of large supplies of ground water in the Lowell area. Also, should this reservoir be developed to the point where sustained withdrawals exceed the natural replenishment, it would be possible to divert surface water from the present channel of the Merrimack River into this abandoned valley to recharge the aquifer.

An analysis of the rock type, yield, and depth relations of wells tapping crystalline bedrock in central Massachusetts, by R. G. Petersen, shows that the yield of the bedrock wells apparently is more dependent upon rock type than upon the depth drilled. The average yield of the wells drilled in schist is about three times that of wells in granite. A true depth-yield relationship cannot be shown by plotting depths against yields nor by calculating average yields of wells for different ranges of depths.

### Surface- and ground-water supplies in Connecticut

Allan D. Randall and colleagues have shown that the positions of major drift-filled bedrock valleys in the Quinebaug basin of eastern Connecticut generally coincide with large present-day streams. However, segments of major bedrock valleys that carry no through drainage today occur near Moosup Pond, Quinebaug Pond, Danielson, Plainfield village, Alexander's Lake, and elsewhere. Thalwegs of the valley system extend slightly below mean sea level only at the lower end of the basin, near Jewett City. The valley fill includes many permeable coarse sand and gravel beds, although these are overlain in places by fine-grained glaciolacustrine and valley-train deposits; saturated thickness very rarely exceeds 100 feet.

Generally, surface waters of the Quinebaug River basin have a moderately low mineral content, as is commonly the case in other areas of crystalline bedrock. The principal ions are calcium, sodium, bicarbonate, and sulfate, according to C. E. Thomas, Jr. Dissolved solids range between 21 and 74 ppm, and hardness between 7 and 36 ppm. However, in water from the Quinebaug River and some major tributaries, the dissolved solids range from 31 to as much as 200 ppm, due to industrial waste. The highest concentrations occur along the French River and the Quinebaug River above Putnam.

## NEW YORK

### Pleistocene aquifers of Queens County

Contour mapping of the buried pre-Pleistocene surface of Queens County by Julian Soren shows channels eroded in the Cretaceous deposits to depths as great as 500 feet below sea level. These channels contain coarse sand and gravel deposits of pre-Wisconsin and Wisconsin age, separated in places by the interglacial Gardiners Clay. The permeable deposits are important artesian and water-table aquifers.

### Water quality of the Delaware River

Study of water quality in the Delaware River basin in New York by J. A. Shaughnessy [26] indicates that the chemical quality of the surface water is excellent. The dissolved-solids content ranges from 20 to 76 ppm and the hardness from 9 to 48 ppm. In the ground water, the dissolved-solids content ranges from 28 to 481 ppm and the hardness from 16 to 109 ppm. During the period Feb. 14, 1957 to Sept. 30, 1959, suspended-sediment concentrations of the Delaware River at Port Jervis were generally low, and the daily mean concentrations exceeded 100 ppm only 2 percent of the time.

The temperature of the Delaware River at Port Jervis and the Neversink River at Godeffroy was less than 75°F on 90 percent of the days measured; ground waters in the basin were generally slightly above the annual mean air temperature for the area (about 50°F at Port Jervis).

### Water-table changes in Kings and Queens Counties, New York City

N. M. Perlmutter and Julian Soren (1–63) report that cessation of pumping from a large well field in Brooklyn in 1947 has resulted in recovery of the water table of as much as 40 feet through 1962. This has alleviated sea-water encroachment problems, but has created seepage problems in the subway system and in inadequately waterproofed basements constructed during the preceding low water-table period.

## NEW JERSEY

Studies of the hydrogeochemistry of the ground waters of the coastal plain of New Jersey and several countywide investigations indicate that the principal sources of ground water are sand aquifers in formations of Late Cretaceous age (Raritan, Magothy, Englishtown, Wenonah, Mount Laurel) and to a lesser extent Tertiary deposits, chiefly the Cohansey Sand. Ground water from these deposits is generally of satisfactory quality for most uses, but locally may require treatment for excessive iron or hardness, or to adjust the pH.

### Availability of ground water in the coastal plain

Studies in Mercer County by John Vecchioli and M. M. Palmer, in Gloucester County by W. F. Hardt and G. S. Hilton, in Salem County by J. C. Rosenau and others, in Burlington County by F. E. Rush, in Monmouth County by L. A. Jablonski, and in Cape May County by H. E. Gill (1–62) indicate that supplies sufficient for domestic and stock use can be obtained at reasonable depth (less than 200 feet) almost anywhere in the coastal plain. Larger municipal or industrial supplies can be obtained in most of the coastal plain by properly drilled wells less than 1,000 feet deep. The principal problem in these larger supplies is obtaining sufficient yield without excessive drawdown, and intrusion of salty water from the sea or from underlying connate marine waters.

### Salt-water intrusion in coastal areas

Intrusion of saline water, of course, is most serious along the Atlantic coast and the Delaware River estuary and locally imposes severe limitations on

[26] Shaughnessy, J. A., 1963, Water quality in the Delaware River basin, New York: New York State Dept. Commerce Bull. 5.

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ground-water development. In Cape May County, for example, Gill found that the deposits below 1,000 feet contain saline water and that landward encroachment of salt water has occurred at the southern tip of the county. Most of the ground-water supply is obtained from the Kirkwood Formation and the Cohansey Sand (Tertiary), as the underlying Cretaceous deposits contain salty water.

### Core hole to basement rocks on the Atlantic coast

A core hole drilled at Island Beach State Park, on the Atlantic coast midway between Atlantic City and Asbury Park, was designed to test the water-bearing character of the entire Cretaceous and younger sedimentary section at its most easterly point. The hole reached biotite gneiss of the basement complex at 3,798 feet. P. R. Seaber and John Vecchioli (Art. 26) report that the sedimentary sequence indicates generally deeper water deposition than the outcrop section, but that the sequence is similar in that continental and transitional deposits underlie and overlie glauconitic marine sediments.

H. E. Gill and others report that the most significant differences, in comparison with the section where it is exposed along the western border of the coastal plain, are: (1) the sand aquifer of the Englishtown Formation is missing, (2) the Mount Laurel Sand thins coastward, (3) the Kirkwood aquifer is finer grained, and (4) the Cohansey Sand is represented by a clay sequence. The Raritan Formation, which is 1,728 feet thick, contains fresh water in its upper part, but the chloride content increases with depth to about that of sea water, at the base of the formation.

### Fresh ground water beneath the coastal plain

The sediments underlying the Atlantic Coastal Plain of New Jersey contain vast quantities of fresh ground water. Except for salt-water encroachment in several small areas, where an aquifer system is locally exposed to a saline surface-water body, no massive salt-water encroachment has been observed in any of the aquifer systems. Geologic data indicate that the aquifer systems have poor hydraulic continuity with the ocean. Chemical data analyzed by Paul R. Seaber (1–63) show no increase in chloride concentration, with time, in water from wells tapping several aquifer systems; some records date back to 1923. Measurements of piezometric head indicate a seaward hydraulic gradient in the major aquifers throughout most of the coastal plain; only locally in a few areas of heavy pumping is the gradient landward.

### Quality of the Delaware River at Trenton

Because of its importance in water supplies in the Philadelphia area, the Delaware River is under continuous study. L. T. McCarthy and W. B. Keighton report that in the 17-year period from 1945 to 1961 the Delaware River at Trenton, N.J., was of excellent chemical quality. The average concentration of dissolved solids was 86 ppm, and 90 percent of the samples ranged from 57 to 126 ppm. Hardness of the river water was less than 86 ppm 95 percent of the time, and most of the time the water was nearly neutral (pH 7). The mineral content is lowest during March, April, and May (median concentration of dissolved solids, 66 ppm) and highest during August and September (median, 107 ppm).

The discharge of the Delaware River at Trenton is regulated by upstream reservoirs which store water in times of surplus and release it to the stream when the natural discharge is low. These controlled releases, augmenting the low flow, improve the chemical quality of the water at Trenton and narrow the range of concentrations of the dissolved constituents. In 1962 the range in dissolved-solids concentration was 54 percent less, and the mean-annual dissolved-solids concentration was 15 percent lower than would be expected for the natural flow. By 1965 another large reservoir will be in operation; it is estimated that the range in dissolved-solids concentration will then become 71 percent less than under natural-flow conditions.

An average of 880,000 tons of dissolved solids and 932,000 tons of suspended solids each year are carried past Trenton by the Delaware River. The greatest monthly loads of dissolved solids are in March and April, the smallest from July to October. Suspended-solids loads are greater when the streamflow is high, but small the rest of the time. The concentration of pumps and extend the storage life of the offstream the time.

### Sediment content of the Raritan River

An analysis of suspended-sediment data collected on the South Branch Raritan River by J. R. George shows that peak sediment concentrations often occur up to 3 hours before the storm-runoff peaks at Stanton, N.J. This information will allow the State Division of Water Policy and Supply to be more selective in pumping water from the river to an offstream reservoir. Avoiding pumping during periods of unusually high sediment concentration will reduce wear on the pumps and extend the storage life of the offstream reservoir.

## PENNSYLVANIA

### Quality of the Susquehanna River

Studies of the chemical quality of the West Branch Susquehanna River indicated to E. F. McCarren

(1-63) that at least 100 miles of the river is affected by tributaries that carry acid wastes from bituminous coal mines in Clearfield and Cambria Counties. Offsetting the effects of the acid water are other tributaries that drain areas underlain by limestone, which are alkaline and generally low in dissolved-solids content.

### Systems analysis of Swatara Creek basin

By applying systems-analysis techniques in a hydrologic study of Swatara Creek basin, W. T. Stuart, W. J. Schneider, and J. W. Crooks have related streamflow patterns, ground-water yield, and water quality to the basin's natural and manmade environment.

Five general zones based on different streamflow characteristics have been delineated within the basin at average low-flow conditions. The natural yield of streams ranges from less than 0.01 cfs (cubic feet per second) per sq mi to more than 0.40 cfs per sq mi for the various zones. However, flows in excess of 1.0 cfs per sq mi occur in some areas as a result of such cultural influences as urbanization and coal mining.

Chemical characteristics of water in the basin have been similarly classified. Concentrations of dissolved solids range from 25 ppm to more than 1,000 ppm. During low flow, the chemical character of surface water is about the same as that of the local ground water. Differences were noted where streams flow through more than one zone or where the water is altered by coal mining or other human influences.

Generally, the availability of ground water corresponds to the base flow of the streams. In areas of high stream base flow, wells of moderate yield are common; where the rocks are fractured or porous the yield is even higher. In areas of low base flow, wells of low yield prevail. However, in limestone terrane, where the water table is deep below the land surface and base flows are generally low, wells yield little water unless a solution channel is intersected below the water table. If a solution channel is tapped, large yields are probable.

### Low flows in Pennsylvania streams

W. F. Busch and L. C. Shaw have prepared a minimum-runoff map for Pennsylvania using streamflow records for 65 long-term gaging stations. Based on a computer analysis, average 7-day minimum flows having a 2-year recurrence interval were used to divide streams in the State into three categories on the basis of flow: less than 0.1 cfs per sq mi, 0.10 to 0.20 cfs per sq mi, and over 0.20 cfs per sq mi.

### Early Paleozoic aquifers of Lebanon Valley

Among the carbonate rocks of Cambrian and Ordovician age in the Lebanon Valley, Harold Meisler found that the most reliable sources of ground water are the Schaefferstown and Milbach Members of the Conococheague Limestone, and the Stonehenge and Ontelaunee Formations of the Beekmantown Group. The least reliable sources of ground water are the Snitz Creek Member of the Conococheague Limestone, the Epler Formation of the Beekmantown Group, and the Hershey Limestone. The nonshaly limestone aquifers generally yield larger supplies of water to wells that do the dolomite or shaly limestone aquifers.

### Long-term ground-water fluctuations

Long-term records of ground-water fluctuations were studied by C. W. Poth as part of the reappraisal of the observation-well program in Pennsylvania. These records, ranging up to 32 years in length, show no secular trend toward either higher or lower water levels. Cycles other than the annual cycle were not noted, but sequences of above- or below-average water levels of several years duration are evident.

### Bedrock aquifers of Dauphin County

A ground-water investigation by L. D. Carswell and J. R. Hollowell in Dauphin County indicates that water in the Martinsburg Shale is transmitted principally through joints. These joints are best developed in competent beds of siltstone, sandstone, and cherty mudstone and are poorly developed in the less competent shale. The Martinsburg contains some beds of limestone, and wells are known to yield from solution openings in these beds. No wells yielding more than 200 gpm have been reported in the area. Typical wells yield 10 to 50 gpm from the competent beds and 1 to 10 gpm from the shale.

## MARYLAND

### Ground-water resources in the Lower Potomac–Chesapeake Bay area

An appraisal of the potential ground-water supplies in Anne Arundel County indicates that substantial quantities of ground water are available for future needs (Mack, 1-62). Most of the current water-supply problems in the area are caused by the high iron content and corrosiveness of the ground water, especially in the area north of Annapolis. The median concentration of iron in water from all the major aquifers is above the recommended limit of 0.3 ppm; in two aquifers, the Raritan and Magothy Formations, the median iron content is more than 8 ppm (Richardson, 1-62).

Preliminary findings by F. K. Mack in a ground-water investigation of Prince Georges County indicate that water levels in some aquifers of Cretaceous age have been lowered by substantial pumpage in industrial areas in adjacent counties in Virginia. Nevertheless, substantial untapped reserves of ground water of good quality are available in the central and southern parts of the county.

Coastal plain deposits in Charles County do not contain the thick, productive aquifers present in strata of comparable age at Baltimore and Annapolis. T. H. Slaughter concludes that the proportion of permeable sand in the deposits is less in Charles County than it is to the northeast and that the transmissibility of the deposits accordingly is lower.

### Iron in ground water of the Eastern Shore

In a study of the cause of decreased yields of municipal wells at Salisbury, S. G. Heidel found that both ferrous iron (up to 1 ppm) and dissolved oxygen (up to 8 ppm) are present in the aquifer tapped. Oxidation of ferrous iron to ferric iron and precipitation of iron oxide may be expected as a result of this unstable condition. Field observations suggest that water leaking from an underlying aquifer having a higher iron content (4 ppm or more) is mixing with water from the principal aquifer.

## VIRGINIA

### Structural control of ground water in consolidated rocks

According to F. W. Trainer, joints in layered rocks in parts of Virginia, West Virginia, and Maryland occur in a few simple patterns which apparently are related to the present attitude of planes of weakness—bedding in the sedimentary rocks, or the best-developed foliation in the metamorphic rocks. This observation suggests that, in the Paleozoic sedimentary rocks of the central Appalachian region, joints were formed after the Paleozoic folding. Joint patterns are significant hydrologically as a major control of the premeability of fractured rocks.

## WEST VIRGINIA

In a recently completed report on the hydrology of West Virginia, W. L. Doll, Gerald Meyer, and Roger Archer have summarized data on the availability, chemical character, and characteristics of occurrence of water throughout the State. In the mountain and hilly plateau lands of central and western West Virginia, streamflow decreases sharply during the summer and fall evidently because of low ground-water storage capacity in the underlying rocks, principally sandstone and shale. In contrast, streams in the limestone areas of the eastern part of the State have generally higher dry-weather flows.

### Hydrology of the Monongahela River basin

Preliminary studies of the hydrology of the Monongahela River basin in northern West Virginia show that the water of most headwater streams is of good to very good quality. Waters in the Cheat River basin, a major tributary to the Monongahela, also are of good chemical quality. Generally these waters are soft and have low mineral content. On the other hand, the West Fork River, which drains the western part of the Monongahela basin, and the lower reaches of the Monongahela River yield water that requires extensive treatment for many uses.

## NORTH CAROLINA

### Availability and geochemistry of ground water

Preliminary findings by Robert L. Laney in a geochemical investigation of western North Carolina suggest that the percentage of silica in the water is a useful indicator of the source of the water. Chemical analyses of rainfall are similar to analyses of water from springs except for the amount of silica. Rainfall contains practically no silica, whereas silica in the ground water ranges from 24 percent of the total dissolved solids in areas underlain by mica schist to 45 percent in areas underlain by granitic gneiss.

Ground-water reconnaissance studies in Haywood, Jackson, and Macon Counties in western North Carolina by Owen T. Marsh (1–63) indicate that at least 10 principal water-bearing units can be mapped in that area. Auger-drilling of flood-plain deposits showed that the deposits consist mainly of sandy clay capped by a veneer of gravel and are not favorable sites for ground-water supplies.

### Geochemistry of coastal-plain ground water

Preliminary findings by Hugh B. Wilder in a geochemical study in the coastal plain of North Carolina indicate that, generally, the sediments in the area can be divided into three geochemical zones. Zone 1, consisting of post-Miocene deposits, characteristically yields acid water (pH 4.5–6.5) containing objectionable amounts of iron (1–25 ppm) and usually containing less than 250 ppm total dissolved solids. Zone 2, consisting of sediments of Miocene, Eocene, and parts of the Paleocene series, yields slightly basic water (pH 7.0–7.5) of calcium bicarbonate type, with unusually high concentrations of silica (30–50 ppm). Water from the Paleocene rocks contains fluoride in amounts up to 4 ppm. Water percolating from zone 1 down into zone 2 rapidly loses its high iron content and become hard. Zone 3, consisting principally of deposits of late Cretaceous age, yields water of sodium bicarbonate type which is low in hardness (7–50 ppm as $CaCO_3$), basic (field pH 7.6–8.2), and high in alkalinity (up to 600 ppm as $HCO_3$). In the immediate coastal areas, one or more of these zones may be contaminated with salty water, and in many areas the only potable source of supply is zone 1.

## SOUTH CAROLINA

### Annual runoff, by physiographic province

Streamflow records in South Carolina indicate that the maximum average annual runoff occurs in the Blue Ridge province and exceeds 40 inches. According to F. W. Wagener, the annual runoff decreases gradually, toward the southeast, to a minimum of 10 inches in the lower Piedmont province, then increases to more than 14 inches along the eastern border of the Piedmont where the streams drain areas of sand hills. Average annual runoff decreases across the coastal plain to less than 10 inches, except near the North Carolina line, where it remains at about 14 inches.

### Ground water in basement rocks beneath the coastal plain

On the basis of the observation wells in several parts of the South Carolina coastal plain, G. E. Siple has noted that ground water occurs under artesian conditions in the fractured upper part of crystalline basement rock, buried under 300 to 1,000 feet of coastal plain sediments. The water is confined by an extensive layer of saprolite 30 to 60 feet thick, and the hydrostatic head of the water in the crystalline rocks is higher than that in several of the overlying coastal plain aquifers.

### Controls on well yield in the Piedmont province

Current ground-water studies of Greenville County in the Piedmont province indicate that topography is the major control on well yield; the higher yields are obtained from wells located on slopes, draws, or valleys, and lower yields from wells on hills or plateaus. Although the rock type also has an important bearing on yield, these studies show that in this area the topography has an even greater effect.

## GEORGIA

### Base flow from Paleozoic rocks

In a study of the Paleozoic area of Georgia, Charles Cressler found that during the annual low-flow period, springs in Catoosa, Walker, and Chattooga Counties discharge more than 75 mgd. About 50 mgd are unused, but help to maintain streamflow. Most of the spring water has a hardness of less than 150 ppm and an iron content of less than 0.1 ppm. The largest flow observed was 13 mgd.

### Movement of water in the principal aquifer near Savannah

Deep-well current-meter studies of the principal artesian aquifer in the Savannah area, Georgia and South Carolina, have indicated the presence of 5 major water-yielding zones separated by relatively impermeable zones. The 3 uppermost zones are in the Ocala Limestone of late Eocene age and the 2 lowermost zones are in the Lisbon Formation of middle Eocene age. M. J. McCollum reports that sea water is entering the upper zones in the northeastern part of the area and moving slowly toward the center of pumpage at Savannah. In the lower water-yielding zones, unflushed salty water of an older geologic age is moving toward the center of the cone of depression at Savannah.

### Sources of base flow in the Yellow River basin

A hydrologic investigation by F. A. Kilpatrick and O. J. Cosner in a small basin in the Yellow River area has determined the amounts that two aquifers beneath the flood plains contribute to base flow. One aquifer is made up of jointed crystalline bedrock, and the other, alluvium that is hydraulically continuous with the stream. The joints of the bedrock aquifer are tightly sealed at its upper surface, thus impeding discharge to the stream. Both aquifers contribute significantly to base flow, but only the bedrock aquifer contributes during periods of low base flow.

### Saline ground water at Brunswick

Test drilling at Brunswick has led R. L. Wait (2–62) to conclude that fresh water is present in limestone between depths of 500 and 1,000 feet. Brackish water containing as much as 320 ppm chloride is present in hard dense cherty dolomitic limestone and gray fossiliferous limestone between 1,030 and 1,400 feet. Municipal and industrial wells that tap the brackish-water zone yield water with a high chloride content. Cementing the bottom part of the wells will improve the quality of water, decreasing the chloride and dissolved-solids content and the hardness.

## FLORIDA

A large part of the water investigations in Florida is directed toward study of fresh-water-salt-water relations. Both surface streams and ground water are subject to salt-water intrusion. In coastal areas the main hazard is intrusion of sea water; inland the main hazard is upward migration of salty water from deep aquifers that have not been flushed of sea water since Pleistocene time.

### Recharge and discharge of principal artesian aquifer

In Florida, Georgia, and in adjacent parts of South Carolina and Alabama, the principal artesian aquifer, consisting of permeable limestones of early Tertiary age, is one of the most extensive and productive aquifers known. V. T. Stringfield reports that it is a source of water for thousands of wells throughout the region and some of the laregst limestone springs in this country. The aquifer is recharged not only where it is at or near the surface, but in some lake regions in Florida and Georgia where it is as much as 200 feet below the surface.

Water in the principal artesian aquifer in Seminole County is derived from rain falling on the principal recharge areas of central Florida and from recharge areas in the county, according to J. T. Barraclough (1–62). The artesian pressure head has declined only slightly and the chloride content of the water has changed little since 1933. Salt water in the principal aquifer appears to be the result of infiltration of sea water during Pleistocene time. Flushing of salt water has progressed farther in the upper part of the aquifer than in the lower part. Almost all the wells that yield salty water are in areas where the land-surface elevation is less than 30 feet above sea level and the head available for flushing therefore is low.

### Salinity of the streams of the Florida peninsula

Studies of the chemical quality of the surface waters of Florida indicate marked variations in salinity due largely to variations in the source of recharge. B. F. Joyner reports that water in the St. Johns River became very saline during the drought in the spring and early summer of 1962. A chloride concentration of 1,180 ppm was measured just upstream from Lake Harney in Volusia County. Below Lake Harney the inflow from several large springs improved the quality of the water downstream to tidewater at Palatka. The quality of the water in the river improved as flow increased during the summer rainy season.

A study of the quality of the water of several springs at low and high stages of the St. Johns River indicates that the dissolved-solids content remains fairly constant in the water from some springs, varies inversely with discharge for other springs, and varies directly with discharge for two springs.

A study by B. F. Joyner, J. D. Warren, and H. Sutcliffe, Jr., shows that marked variation in the quality of water in the Myakka River basin is due to contamination by poor-quality ground-water irrigation waste from lands served by artesian wells and water from uncapped flowing wells.

### Salt-water intrusion into ground-water supplies

Because ground water is the major source of irrigation and municipal supply in much of Florida, many of the Survey's investigations are directed toward safeguarding this resource from salt-water encroachment.

W. E. Clark found that highly mineralized water was intruding the shallow artesian aquifers from which the city of Venice, on the west coast south of Sarasota, draws its water. The highly mineralized water was moving up uncased well bores from the deeper Floridan aquifer. Similarly, investigations by Howard Klein, M. C. Schroeder, and W. F. Lichtler (1–62) have delineated areas of salt-water contamination in the shallow aquifer in Hendry and Glades Counties, in southern Florida, particularly near LaBelle in Hendry County, and in an area along the western shore of Lake Okeechobee in Glades County. The contamination at LaBelle can be directly traced to upward leakage of deep artesian water under high pressure through open deep-well bores into shallow sediments. The contamination near Lake Okeechobee may be attributed to unflushed sea salt as well as to upward leakage.

Studies in Collier County in southwestern Florida by H. J. McCoy (1–62) show salty water in a deep artesian aquifer and generally fresh water in an extensive shallow aquifer. The shallow aquifer is contaminated, however, by modern sea-water intrusion in coastal areas and by residual salt water of ancient seas in some inland areas.

G. R. Tarver (1–63) found that wells tapping highly permeable limestones near Pompano Beach in Broward County were protected from salt-water intrusion by overlying less permeable sandy materials.

J. T. Barraclough and O. T. Marsh (2–62) reported three aquifers separated by clay beds in westernmost Florida. Around Fort Walton Beach the artesian-pressure head in the upper limestone of the Floridan aquifer has declined 95 feet since 1936. This decline has caused incipient salt-water encroachment, probably due to upward movement of salt water from the lower limestone.

### Water management in the Miami area

Municipal water-use studies in the Dade–Broward County area of southeastern Florida show that supplies totaling more than 1 billion gallons per day may be required within 25 years. However, studies by Howard Klein, C. B. Sherwood, and S. D. Leach indicate that ground-water supplies of this magnitude can be obtained, without increased sea-water intrusion, by the maximum use of the water-management system of the Central and Southern Florida Flood Control District. The network of controlled canals of this system connects Lake Okeechobee and large inland water-conservation areas with the coast and provides large quantities of fresh water for recharge by infiltration into the highly permeable Biscayne aquifer. Because of the excellent interconnection between canals and coastal parts of the aquifer, control of water levels and canal flows may be accomplished on a regional basis.

#### Relation of ground-water levels to climatic fluctuations

The period September 1960–May 1962 produced two extreme hydrologic conditions in southeastern Florida. Intense rainfall that accompanied Hurricane Donna and tropical storm Florence in September 1960 caused extensive flooding in southern Dade County, where the drainage system was inadequate. The intense prolonged drought of November 1960–May 1962 resulted in the opposite extreme in southeastern Florida. At the end of the drought, water levels throughout most of the Everglades were at record lows. Investigations of well-field areas and individual canal systems by C. B. Sherwood and S. D. Leach (2–62) showed that ground water from the inland areas moved eastward through the improved canal system to furnish continuous replenishment to coastal parts of the aquifer.

Similar effects of wet or dry periods were noted in the Orlando area of central Florida, where piezometric levels fluctuated from a high of 74 feet above msl (mean sea level) in September 1960 to a low of 50 feet above msl in May 1962, according to W.F. Lichtler, Warren Anderson, and B. F. Joyner (1–63). This contrasts with a fluctuation of 5 to 10 feet in surrounding areas of the county. The larger fluctuation in the Orlando area is attributed to greater recharge through the approximately 400 drainage wells in and near Orlando during the record wet period in 1959–60 and heavy ground-water withdrawal during the 1962 drought.

#### Availability of ground water in the Florida panhandle

Large supplies of surface and ground water of excellent quality are available for future industrial development in Escambia and Santa Rosa Counties in westernmost Florida, according to a study by R. H. Musgrove, J. T. Barraclough, and R. G. Grantham. Four major rivers discharge an average of 8.5 billion gallons per day to the sea, and sand and gravel deposits at shallow depth that presently supply 70 mgd could be developed further. The underlying Floridan aquifer is virtually untapped.

#### Effects of pumping in the Jacksonville area

Studies by Gilbert W. Leve indicate that the permeable zones in the Floridan aquifer in northeast Florida are hydraulically separated by thick impermeable zones. Artesian pressures have declined at Jacksonville and Fernandina as a result of heavy pumpage; the rate of decline is greater in the upper part of the aquifer owing to heavy pumpage from that zone.

### VIRGIN ISLANDS

Reconnaissance studies of Cinnamon Bay and Trunk Bay, St. John, Virgin Islands, by P. E. Ward and D. G. Jordan show that beach deposits contain a thin lens of slightly brackish but potable water within about 300 feet of the shore. The water-bearing material is calcareous and ranges in size from silt to medium-coarse sand. No stream on St. John can be identified as perennial but very short reaches of at least two streams probably have small perennial flow.

In a study of the ground-water resources of St. Croix, Virgin Islands, G. E. Hendrickson found that the greatest yields are obtained from wells in limestone and alluvium in the south-central plains area, but the water there is only of fair to poor quality. If properly developed, ground-water resources of the island should be adequate for the present and near-future public supply.

## MIDCONTINENT AREA

Water is generally plentiful in the States of the midcontinent area, and water-supply problems relate chiefly to the availability of large supplies of suitable quality for municipal, industrial, agricultural, and recreational use. Increasing water needs, however, with an accelerated incidence of related water problems, require that additional emphasis be placed on delineation of the problems and determination of their causes and solutions.

In most of the midcontinent States water-resources studies involve appraisal of the available supply and description of the hydrologic environment, with special emphasis on solution of immediate water-supply problems. Large withdrawals of ground water, for example, for rice irrigation in Louisiana and Arkansas, and for municipal and industrial use in Memphis, Dayton, and Milwaukee, have been evaluated in terms of their effect on quantity and quality of water available. Other studies are concerned with contamination of fresh-water resources by acid mine wastes and oil-field brines and by intrusion of saline water into fresh-water aquifers. Flooding potential and deficiency of streams during low-flow periods pose serious problems affecting optimum use and management of surface-water resources and are under investigation. The significant results of these investigations are reported in the following section.

## MINNESOTA

### Melt-water channels near Marshall

Near Marshall in southwestern Minnesota, G. L. Thompson found that tone difference in areal photographs could be used to map narrow surficial melt-water channels that cross a major outwash sluiceway obliquely. Permeable sand and gravel are found on the inside of the meander bends of the surficial channels. Wells tapping these deposits yielded 1,500 gpm, whereas wells less than 100 feet away yielded less than 50 gpm. Before the identification of the channel the town of Marshall had drilled several unproductive holes in the sluiceway.

### Quality of ground water in the St. Paul–Minneapolis area

Investigations of the chemical quality of ground water, by M. L. Maderak, in a 2,900-square-mile area in the vicinity of Minneapolis and St. Paul indicate that unconsolidated Pleistocene deposits, and rocks of Ordovician, Cambrian, and Precambrian age are the principal sources of ground water and that the water is generally of calcium bicarbonate type. In general, water in the aquifers of Pleistocene, Cambrian, and Precambrian age increases in amount of dissolved solids from east to west across the area, probably largely because of the increase in thickness and the change in composition of glacial deposits from east to west.

Change in the quality of the ground water with time is minor, except where contamination is a problem. Contamination from human wastes, indicated by high concentrations of nitrate, was noted in two communities that obtain water from aquifers in the glacial drift. At both places, concentrations of nitrate above 45 ppm at depths of about 50 feet suggested possible contamination of water in rocks of Ordovician age.

## WISCONSIN

### Ground water in Pleistocene deposits

C. L. R. Holt, Jr., has found that extensive outwash plains in Portage County are the potential source of large quantities of ground water. Pumpage of ground water can be greatly increased without seriously affecting ground-water levels.

A study of the ground-water resources of Waushara County, by W. K. Summers, shows that large supplies of ground water of generally good quality, except for excessive hardness and locally high iron content, are available to wells over a large part of the county, principally from thick deposits of sand and gravel outwash of Pleistocene age. The potential available supply is far greater than the present annual rate of withdrawal and, in some areas, will support a large increase in use.

Thick glacial outwash sands and gravels in the deep ancestral Rock River valley in Rock County have been found by E. F. LeRoux to be a source for large supplies of ground water. The 20 mgd of water withdrawn in 1957 represented only about 12 percent of the potential daily withdrawal.

Denzel R. Cline (1–63) found that Dane County, in south-central Wisconsin, has adequate ground-water supplies to meet future needs for many years even though pumpage is expected to double by 1980. Pumpage from wells in the Madison metropolitan area in 1959 represented 73 percent of the total pumpage in the county. The streamflow of the upper Yahara River was decreased by an amount about equal to the pumpage.

A study of the ground-water resources of Waupaca County, by C. F. Berkstresser, Jr., shows that moderate to large supplies of ground water of good quality, except for excessive hardness and iron, are available to wells over most of the county, principally from outwash sand and gravel of Pleistocene age. Sandstones of Cambrian age also are an important aquifer in the southeastern part of the county. The average annual rate of withdrawal is far below the potential available supply.

### Ground-water pumpage in Milwaukee–Waukesha area

A study of the heavily pumped Milwaukee-Waukesha area, by Roy W. Ryling and Rickard D. Hutchinson, has shown that the center of the cone of depression stabilized during the past 11 years while the cone expanded toward the northwest and deepened more than 100 feet. This decline was due to a redistribution of pumpage centers toward the recharge area.

## MICHIGAN

### Quality of surface water on Isle Royale

A reconnaissance of the water quality on Isle Royale, by C. R. Collier, indicated that the streams have a soft calcium bicarbonate type water that is low in dissolved solids but highly colored. The igneous bedrock is resistant to chemical erosion, which results in the low dissolved-solids content (52–139 ppm) of the water. The high color values (2–75) are contributed by dissolved organic material in the water drained from the swamps. The annual sediment yield of streams draining Isle Royale is expected to be less than 20 tons per square mile. Most of the land surface is protected from erosion by an extensive natural forest; and small unforested areas, old fire scars, or swamps have good vegetal cover. The many outcrops of igneous rock are resistant to weathering and contribute little sediment to the streams.

### Increase in ground-water pumpage at Lansing

Water-level measurements in the Lansing area, Michigan, show that the cone of depression in the piezometric surface has expanded considerably since 1945 as a result of an increase in pumpage from about 17 mgd to more than 25 mgd. Analysis of flow nets by Alli Firouzian and K. E. Vanlier indicates that the Saginaw Formation, the principal aquifer of the area, has an average transmissibility of 23,000 gpd per ft and that about 3 mgd is recharged to the formation from the Grand River. Flow nets also indicate that about 220,000 gpd per sq mi is recharged to the formation from precipitation.

### Salty ground water along shore of Lake Superior

K. E. Vanlier, in a ground-water study of Alger County (1–63), found that the Jacobsville Sandstone of Precambrian or Cambrian age yields salty ground water along the shore of Lake Superior in the western part of the county. The area of salty water coincides with a postulated extension of the Keeweenaw fault.[27] The study indicated that the permeability of the well-cemented Jacobsville is the result of fracturing. Generally, the number and size of fracture openings and the permeability of the sandstone decrease with depth. In the area of salt water, however, the sandstone may be permeable at depth as a result of fracturing along the fault zone. A permeable zone along the fault would provide an avenue of movement for saline water migrating from the Michigan basin.

### Surface-water potential of North Branch Clinton River

Surface-water investigations in the North Branch Clinton River basin near Mt. Clemens indicate very little water-supply potential in the streams draining the lake plains that comprise about three-quarters of the watershed. The summer dry-weather flow recedes to zero in many of the small watercourses in the basin. Small perennial flows have been noted in the headwaters of Coon, East Branch Coon, and Deer Creeks, but these waters are dissipated by evapotranspiration and seepage so that there is little or no flow in the downstream reaches. Streams originating in the moraines and deltas in the western part of the basin all have perennial flow and a greater dry-weather flow, but because the flow is relatively small they cannot support large uses either.

[27] Thwaites, F. T., 1935, Post-conference day No. 2, Monday, September 2, 1935, Duluth, Minnesota to Ironwood, Michigan: Kansas Geol. Soc. 9th Ann. Field Conf. Guidebook, p. 221–238.

### Base flow in streams draining east slope of Marquette moraine

S. W. Wiitala, R. L. Knutilla, and T. G. Newport attribute the very high base flows of streams draining the eastern slope of the Marquette moraine near Harvey to discharge of underflow from a large ground-water source underlying the adjacent East Branch Escanaba River basin. Discharge measurements made in August 1962 on Big, Cedar, Cherry, and Silver Creeks, all tributaries of the Chocolay River, disclose base-flow yields ranging between 1.2 and 4.2 cfs per sq mi. Cherry Creek at the Marquette Fish Hatchery showed the highest yield, 21 cfs from 5 square miles of drainage area. In contrast, concurrent base-flow yields in the adjacent Escanaba River basin were generally less than 0.3 cfs per sq mi. Streamflow in the general area was relatively low, at flows estimated to recur about once in 4 or 5 years. The physical characteristics and abundance of the flow in the Chocolay tributaries clearly indicate a large nearby ground-water source, probably beneath the East Branch Escanaba River basin, which lies on the upland just to the west. Ground elevations in the East Branch basin are more than 500 feet higher than the measurement sites on the Chocolay River tributaries.

### Quality of surface water in Marquette Iron Range

Surface waters in the Marquette Iron Range are of the calcium bicarbonate type, near neutral, and generally soft to moderately hard. E. L. Skinner reports that dissolved oxygen is abundant, with 60- to 80-percent saturation in the most mineralized streams and 100 percent or supersaturation in the less mineralized and turbulent streams. High color values that range from 50 to near 200 are due to drainage from swampy peat beds. Although the iron deposits of the Marquette Range provide an extensive source for possible iron contamination, less than 1 ppm iron is generally present, because the stream waters are nearly neutral (pH 7).

## OHIO

### Quality of the Miami River

G. W. Whetstone reports that above Dayton the water in the Miami River and its principal tributaries, the Mad and Stillwater Rivers, is of calcium magnesium type and the range in the concentration of dissolved solids is from 200 to 450 ppm. The parameters used to measure pollution, that is, dissolved oxygen, threshold odor, pH, biochemical oxygen demand, and phenol, are generally below the maximum permissible limits placed on the substances in water by health authorities.

Below Dayton, the Miami River is heavily polluted, and during periods of low runoff, the dissolved-oxygen content of the water in this reach of the river is so low that the normal biological processes of self-purification are greatly impeded. Substances such as phenols are present in amounts offensive to domestic water users, and the esthetic value of the water resource is reduced by excessive concentrations of ABS, sediment, and trash.

#### Effect of a farm pond on streamflow

Preliminary analyses by W. P. Cross of the runoff measured from 79 acres in central Ohio (annual precipitation 35–40 inches) for 13 years reveals the effect of a stock pond, regulating the runoff from 41 acres, which was constructed at the end of the 5th year of record. Evaporation loss from the pond is about 35 to 40 inches. Ground-water levels downstream from the pond are higher, low flows are maintained for longer periods, and high flows are slightly reduced, but major floods are not materially affected by the stock-pond storage.

#### Hydrologic atlas of Ohio

Maps of Ohio showing average annual streamflow, precipitation, apparent water loss, and mean temperature have been prepared for the period 1931–60. Anomalies in the water-loss map appear to be associated with soil characteristics. A plot of average water loss against average temperature shows little scatter except for small drainage areas with intermittent flow. The study suggests that flow of ground-water beneath topographic divides is relatively insignificant or absent, and that the long-term runoff is determined by the rainfall and temperature.

#### Ancestral Ohio River valley near Cincinnati

A shallow seismic-refraction survey by J. S. Watkins (3–63) shows that the bedrock floor of a preglacial valley in Hamilton and Butler Counties believed to be part of the ancestral (pre-Illinoian) Ohio River valley is nearly flat, but that the valley walls are steep. The valley floor slopes about 1 foot per mile to the southeast. Bedrock in the center of the valley is buried in places beneath more than 300 feet of glacial deposits. Overlapping seismic lines indicated a shallow bedrock ledge in a proposed city of Cincinnati well field. Other lines, however, indicated areas in the well field where the bedrock surface is sufficiently deep to ensure adequate water supplies.

#### Increasing ground-water recharge at Dayton

The chief limitation on the ground-water supply of the Dayton area is the rate at which water can infiltrate the beds of the streams. Discharge measurements made at several points along the Miami and Mad Rivers in October 1960, at low flow, showed that infiltration through the streambeds averaged about 1.7 mgd per acre in spreading ponds on Rohrer's Island but only about 0.07 mgd per acre in the Miami River in the south part of Dayton. The infiltration rate from the river is much higher when the discharge is greater than about 2,000 cfs, which occurs, on the average, about 20 percent of the time. These facts lead to the conclusion that the natural rate of replenishment can be materially augmented by regulation of streamflow or by the use of stream recharge channels and pits.

### INDIANA

#### Low flow of streams

Records of streamflow, analyzed by R. E. Hoggatt (1–62), show that the low flows in the north and central parts of the State are generally much better sustained than those in the south. On most of the streams lying entirely within southern Indiana, the minimum 7-day average flow is zero. A comparison of average annual runoff with average annual precipitation, for the period 1931–60, shows that runoff follows the same general pattern as precipitation.

#### Transmissibility of aquifers in Lake County

Tentative evaluation of the geohydrology of Lake County by J. S. Rosenshein (1–62) indicates that regional values of transmissibility for the principal Pleistocene aquifer and the Silurian aquifer are respectively about 24,000 gpd per ft and 5,500 gpd per ft. Under present conditions, recharge to the artesian part of the Pleistocene aquifer is estimated to average about 100,000 gpd per sq mi. Recharge to the Silurian aquifer is estimated to average about 20,000 gpd per sq.mi.

### KENTUCKY

#### Fresh water at extreme depth in western Kentucky

Fresh water has been found locally in Muhlenberg County at depths as great as 1,100 feet in a basal Pennsylvanian sandstone, according to E. N. Wilson and J. A. Van Couvering. The depth of fresh water in adjacent areas is generally 200 feet or less. Presumably the water is kept fresh by recharge from the surface and migrates rapidly downdip in the relatively permeable sandstone.

#### Ohio River water-bearing deposits

Mapping of alluvial deposits in the Ohio River valley by W. E. Price and J. T. Gallaher has located numerous alluvium-filled buried bedrock valleys or channels not previously known that are potential sources of ground water. The most promising sites for ground-water development are where the Ohio River can recharge the alluvium.

#### Ground water in Jackson Purchase region

Geohydrologic studies in the Jackson Purchase region at the northern end of the Mississippi Embayment by L. M. MacCary, R. W. Davis, T. W. Lambert, and J. H. Morgan show that the Cretaceous and Paleozoic aquifers below the Porters Creek Clay will yield large supplies of water of good quality and will support larger withdrawals than are obtained at present. At least small supplies of ground water can be developed in the outcrop areas of all geologic units younger than the Porters Creek Clay. Fresh water in Devonian limestone at considerable depth presumably is due to the relatively high permeability of the limestone, which has allowed flushing of marine waters by deep circulation of fresh water.

#### Ground water from Pennsylvanian rocks in Cumberland Mountain area

An investigation by D. S. Mull in the Jenkins-Whitesburg area indicated that small to moderately large supplies of ground water can be obtained from beds of sandstone in the Lee and Breathitt Formations of Pennsylvanian age. Near the Pine Mountain fault system, supplies of fresh water are obtained at depths as great as 300 feet; elsewhere in the area, salty water generally is reached below a depth of 200 feet. Evidently the greater number of joints associated with the fault system account for locally higher permeability which permits deeper circulation of fresh water.

#### Surface-water supply in eastern Kentucky

Investigations of water resources of eastern Kentucky by G. A. Kirkpatrick, W. E. Price, and R. J. Madison show that streams, rather than wells, offer the greater potential for development of water supplies in this part of the State. The average yield of streams at low flow was higher in the Cumberland River basin than elsewhere in the region. In some areas, streams are polluted by acid mine drainage, waste brines from oil fields, and untreated sewage. Water from wells is generally of good quality, but wells drilled 100 feet or more into rock may yield salt water.

### TENNESSEE

#### Large additional ground-water supply in western Tennessee

Although new wells are continually being drilled in western Tennessee, G. K. Moore reports that the ground-water supply from aquifers of the Claiborne Group will be adequate for many years to come. Total withdrawal currently is about 157 mgd, whereas the aquifers are probably potentially capable of delivering over 600 mgd. The potential recharge in the outcrop areas of the aquifers cannot be estimated at present but probably greatly exceeds the transmitting capacity of the aquifers. The effects of additional large-scale development will be (1) a drop in local and regional water levels in proportion to the increase in pumpage, (2) an increase in the net inflow of ground water from adjacent States, and (3) an increase of recharge to the aquifers in the areas of outcrop at the expense of surface runoff.

#### Depletion of artesian pressure near Memphis

A study of ground-water conditions in the Memphis area by J. H. Criner, P-C Sun, and D. J. Nyman (1–63) indicates that water-table conditions are being approached in the "500-foot" sand of the Claiborne Group in the southeastern part of the Shelby County, which was artesian before the effect of heavy pumping in Memphis reached the area.

Pumpage from the "500-foot" sand in the Memphis area was about 135 mgd in 1960. According to G. K. Moore the effect of this pumpage has lowered water levels in about 750 square miles of the aquifer outcrop belt in Tennessee and has increased annual recharge from an estimated 0.8 inches of water to 2.2 inches.

#### Residuum forms ground-water reservoir in the Highland Rim

One of the most important factors controlling the occurrence of ground water in the Western Highland Rim is deep weathering of the Fort Payne Chert, according to M. V. Marcher, R. H. Bingham, and R. E. Lounsbury. Residuum derived from the Fort Payne is more than 100 feet thick near Waverly and Hohenwald in Humphreys and Lewis Counties. This residuum acts as a sponge, soaking up rainfall, storing it, and gradually releasing it through springs, thus maintaining the relatively high minimum flow that characterizes the perennial streams of the area. When tapped by wells the residuum locally yields as much as several hundred gallons per minute. Springs draining the residuum commonly have a uniform flow and contain relatively small amounts of dissolved solids.

### ARKANSAS

An investigation of ground-water levels in deposits of Quaternary age in the Grand Prairie area by R. O. Plebuch (1–62) indicates that the cone of depression has enlarged to the northwest between 1953 and 1961. The largest decline of water levels, as much as 9 feet, took place between Stuttgart, in Arkansas County, and

Lonoke, in Lonoke County. Ground-water levels declined from 5 to as much as 16 feet between 1953 and 1961 in parts of western Cross and Poinsett Counties.

Water levels rose in deposits of Quaternary age throughout the area between Crowleys Ridge and the Mississippi River between 1955 and 1962.

## ALABAMA

### Source of iron-free ground water near Selma

A ground-water study in Dallas County by John C. Scott indicates that in updip areas, water in the principal aquifer, the Eutaw Formation of Cretaceous age, generally contains more than 1.0 ppm of iron; downdip to the southwest the water generally contains less than 0.3 ppm of iron. The city of Selma may be able to eliminate the costly process of treating 3 to 5 mgd of ground water for the removal of iron by locating its new well field 1 to 2 miles south or southwest of the present well field.

### Little depletion of ground water in Escambia County

In a ground-water study of Escambia County, Joseph W. Cagle, Jr., and J. G. Newton (1–63) report that water levels and flows of artesian wells tapping the Miocene rocks near Pollard are virtually the same as recorded in 1905 (E. A. Smith [28]). Recharge from underlying limestones of Oligocene age, tapped by few wells in the area, has probably prevented the significant declines noted in similar areas. The hardness of water from the Miocene in the Pollard area and other nearby areas of flow generally exceeds 50 ppm but in areas of nonflow the hardness of water from the Miocene generally is less than 10 ppm. This anomaly indicates that a part of the recharge to the Miocene in areas of flow is from the underlying limestones.

### Surface-water supplies in Tuscaloosa area

A study of the surface-water resources of Tuscaloosa County by L. B. Peirce [29] and R. G. Grantham finds that the county is well supplied with surface water generally of good chemical quality. Annual runoff does not vary greatly over the county and averages about 19.5 inches. Streams in the northeastern half of the county are more variable in flow than those of the southwestern half, but offer better possibilities for the construction of storage reservoirs. Since 1900, damaging floods on the Black Warrior River have occurred once in about 10 years on the average. The temperature of stream water closely follows air temperature and is little affected by variations in discharge except in spring-fed streams. Most of the streams range in temperature from freezing to 90°F, but streams fed by large springs may be as much as 10° cooler than adjacent streams during the summer. In general, the stream waters are low in mineral content. Over a 5-year period, samples ranged in hardness from 6 to 96 ppm.

[28] Smith, E. A., 1907, The underground water resources of Alabama: Alabama Geol. Survey, 388 p.

[29] Peirce, L.B., 1961, Surface water in Tuscaloosa County, Alabama: Alabama Geol. Survey County Rept. 9.

## MISSISSIPPI

### Untapped reserves of ground water

Recent studies by B. E. Wasson (2–63) centered in Attala County and the area to the west and northwest in central Mississippi indicate large reservoirs of fresh ground water in sands of the Wilcox Formation and Claiborne Group (Eocene), some of which are virtually untapped. Electric logs of oil-test borings and selected analyses of water samples indicate that in western Attala County and adjacent Holmes County about 3,000 feet of Tertiary sediments contain several aquifers containing soft to moderately hard water. Individual wells tapping two of the aquifers have been tested at rates of 1,000 gpm or more.

### Potential industrial supply in Mississippi River deposits

Pleistocene sand and gravel deposits along the Mississippi River, south of Natchez, are in hydraulic connection with the river and yield 40–50 mgd for industrial supplies near Natchez with no apparent indication of overdraft, according to E. J. Harvey. These deposits are a potential source of fresh water in a 50-mile stretch between Natchez and the Louisiana line but have not been utilized except in the Natchez area.

### Untapped source of ground water in northeast Mississippi

J. W. Lang and E. H. Boswell report that highly productive untapped aquifers in the Tuscaloosa Group of Upper Cretaceous age were found by a 1,350-foot test well at West Point, Miss. Drilled to the Paleozoic, this well extends the area of known potable water in the Tuscaloosa 20 miles northwestward from an earlier test well, south of Columbus, which flowed 2,300 gpm. The sands of the Tuscaloosa thin rapidly updip (eastward) and wedge out against the Paleozoic surface in south-central Monroe County, but probably become considerably thicker downdip. The sand in the Coker Formation of the lower part of the Tuscaloosa section has been found to be the most important potential source of water for large-capacity wells in all or parts of 10 counties.

### Devonian chert aquifer along Tennessee River

An aquifer in chert correlative with the Camden Chert (Devonian), exposed along the Tennessee River about 25 miles northeast of Corinth, has been found to underlie most of Alcorn County and all or parts of several adjacent counties, where it is a potential source for public and industrial water supplies, according to E. H. Boswell, B. E. Ellison, and E. J. Harvey (1–63). Test drilling revealed that the chert is highly variable in hydrologic characteristics but, in places, yields more than 800 gpm to wells. In other places, secondary cementing of fractures or lack of fractures results in very low yields to test wells. Water quality is superior to that of the shallower Cretaceous deposits, which contain excessive iron.

### Untapped supplies of ground water near Vicksburg

On the basis of electrical logs of oil tests and of known geologic structure, the Warren County Port Commission drilled a 2,206-foot exploratory hole near Vicksburg to test the water-yielding potential of the Sparta Sand of Eocene (Claiborne) age. Although the Sparta includes several hundred feet of sand and clayey sand and stores a large volume of warm (96°F) soft, sodium bicarbonate water of moderate mineral content, E. J. Harvey and J. A. Callahan [30] report that the color would limit its usefulness for many needs. The aquifer, which is not used in the Vicksburg area, has a head of about 40 feet above land surface on the Mississippi alluvial plain and is a potential source of supply for certain industrial and other uses. At Jackson, 40 miles east of Vicksburg, wells tapping the Sparta yield 500–800 gpm for industrial and suburban public supplies.

### Stream losses to Cretaceous rocks in Tombigbee River basin

Studies of base flow by H. G. Golden [31] in the Tombigbee River basin showed appreciable water losses to the sands and gravels of the Gordo and Eutaw Formations from Luxapalila Creek. It was formerly thought that the streams gained water in crossing these formations.

## LOUISIANA

### Ground-water supplies in Mississippi River alluvium

Fresh ground water is available from alluvial deposits of the Mississippi River and older deltaic deposits, all of Pleistocene age, in most of the area along the Mississippi River between Baton Rouge and New Orleans. G. T. Cardwell, J. R. Rollo, and R. A. Long state that yields of 2,000 gpm, or more, of hard water can be obtained from wells 150 to 300 feet deep in the alluvium; wells 200 to 800 feet deep tapping sands in older deltaic deposits yield several hundred to more than 2,000 gpm of soft to moderately hard water. Along the southern margin of the area, and locally in the area, salty water in the base of aquifers limits the development of fresh water.

[30] Harvey, E. J., and Callahan, J. A., 1962, Memorandum on the ground-water potential of the Vicksburg industrial park area, Vicksburg, Mississippi: Mississippi Board Water Comm., duplicated report, 7 p., 2 figs.

[31] Golden, H. G., 1962, Low-flow characteristics, Tombigbee River basin, Mississippi: Mississippi Board Water Comm. Bull. 62–2, 32 p.

### Large amounts of ground water north of Baton Rouge

According to C. O. Morgan, large supplies of fresh ground water are available from fresh-water-bearing aquifers of Tertiary age in East Feliciana and West Feliciana Parishes. Water-level declines of as much as 4.7 feet per year in some aquifers are attributed to large withdrawals in the Baton Rouge area to the south.

### Huge reserves of ground water in southeastern Louisiana

A reconnaissance of southeastern Louisiana by M. D. Winner, Jr., shows an abundant, untapped supply of fresh, artesian water in the unconsolidated Tertiary and Quaternary deposits. Fresh water occurs at depths as great as 3,500 feet below mean sea level, and as many as 10 different aquifers can be tapped at any one site. Total ground water in storage is estimated to be about 240 trillion gallons; withdrawals are about 30 mgd.

### Water levels stabilized in rice-growing district

H. M. Whitman and C. Kilburn report that about 200 billion gallons of ground water was pumped for all purposes from the main aquifer in the rice-farming area of southwestern Louisiana during 1961. Despite large withdrawals, the weighted-average water level as computed for the entire area has remained virtually unchanged since 1955.

### Water-bearing deposits of Vernon and Rapides Parishes

Subsurface studies in Vernon Parish by J. E. Rogers and in Rapides Parish by Roy Newcome, Jr., have shown that the thick water-bearing sequence of Miocene sediments in central Louisiana can be subdivided, on the basis of sandy versus clayey zones, into units corresponding to the exposed members that were mapped by H. N. Fisk in 1940, and by R. N. Welch in 1942.

### Sustained low flows in Vernon and Rapides Parishes

Many streams in Vernon Parish have well-sustained low flow during periods of low rainfall, according to A. J. Calandro. Streams having a drainage area of more than 20 square miles have an average 7-day, 2-year low flow of almost 2 cfs. Streams in the northeastern section have less flow per unit of area than other streams of the parish. Areas of less than 50 square miles in the headwaters of the Calcasieu River will be dry for a 7-day period, on the average, once in 10 years.

Similar studies of the streams of Rapides Parish by Raymond Sloss indicate well-sustained fair-weather flows; however, the runoff in the Calcasieu River basin is less well sustained than that of other streams in the parish. The largest source of surface water is Red River, which had an average flow of 32,400 cfs for the

33 years 1928–60. The water of the Red River is highly mineralized at times, which limits its use for municipal or most industrial uses; however, it is of moderately good quality during the irrigation season.

### Quality of stream waters near Monroe

A study of several streams in the vicinity of Monroe indicates that Bayou Bartholomew could be utilized as an alternate or supplemental source of water for the needs of Monroe, on the basis of acceptable quality, according to S. M. Rogers and S. F. Kapustka. Chloride content is the limiting factor for the Ouachita River as a water source for municipal use. During wet seasons, the Ouachita River is acceptable as a municipal supply for longer periods than during normal or dry seasons. Ouachita River water can be used by pumping into reservoir storage or directly during periods of acceptable quality.

## *ROCKY MOUNTAIN AREA*

All of the six major water problems of the Nation—distribution, supply, variability, chemical quality and sediment load, pollution, and floods, are present in the Rocky Mountain area, which in this discussion includes also Arizona, Texas, and the plains States, but excludes Idaho. The problems of distribution and supply are the most critical and are widely prevalent in the area. Mean annual runoff ranges from as much as 20 inches or more in some of the high mountain areas down to practically zero in the desert regions. Surface flows are highly variable throughout the area, and large dependable supplies require regulation by storage. Losses by evaporation from the soil and from open-water surfaces of ponds, lakes, and streams constitute large items in the water accounting for the area. The consumption of water by nonbeneficial plants is a large drain on available supplies—the rapid infestation of many stream valleys in the southwest by saltcedar constitutes an especially serious problem.

Ground water is of greatest importance, both as a supplement to surface water in some areas and as the only source of supply in many of the arid and semiarid sections, Overdevelopment, with consequent lowering of water tables, is occurring in many areas and has increased the demand for quantitative evaluations of the availability of ground water. There is an increasing interest in the interrelations between surface water and ground water and of the possibilities for management of ground-water reservoirs to supplement surface-water supplies.

Deterioration in the chemical quality of both surface and ground waters has occurred in many areas because of the leaching of salts from the soils by irrigation water. Oil-field brines have contaminated both surface and ground waters in some areas. Although much has been and is being accomplished in the alleviation of this problem through disposal of the brines into deep zones through injection wells, many problem areas still exist. Saline springs, particularly in the Permian basin in parts of Oklahoma, Texas, and New Mexico, contribute large salt loads to streams and seriously limit the utility of some surface waters. Heavy sediment loads in streams draining erodible soils, especially in arid and semiarid areas, constitute serious problems in regard to the siltation of reservoirs and the deterioration of stream channels.

## MONTANA

### Ample ground water from Cenozoic deposits in Missoula Valley

Cenozoic deposits in the Missoula Valley yield 1,000 to 4,000 gpm from wells less than 250 feet deep, according to R. G. McMurtrey, R. L. Konizeski, and A. Brietkrietz. The pumping of about 10 mgd from one part of the valley has caused an average water-level decline of about 7 feet in an area of about 4 square miles.

### Buried valley of Yellowstone River yields water

Finding the buried valley of the ancestral Yellowstone River west of Sidney resulted in the drilling of a municipal well capable of yielding more than 1,000 gpm of good quality water, according to F. A. Swenson. Numerous wells of low yield drilled in the past all found less than 50 feet of water-bearing sand and gravel; more than 110 feet of aquifer at the well site in the ancient channel west of town is indicated by the study of the U.S. Geological Survey.

### Streams disappear into Madison Limestone in Judith River basin

In the western Judith River basin, E. A. Zimmerman observed that several streams with a flow as much as 20 cfs disappear entirely into sinks in the Mississippian Madison Limestone. No discharge from the Madison was found in the study area.

### Mud springs in Judith River basin

In the same area Zimmerman found interesting mud springs, locally called "geysers," in the vicinity of Geyser. In the springs, fluid bentonitic mud stands at the land surface, and quaking ground surrounds the main vents, but little or no mud issues from the mud springs. One of the springs was pumped down 3 feet, and about 1 month was required for recovery of the fluid level. It is thought that the springs are artesian and that flow is impeded by the weight of the bentonitic mud in the vents.

## NORTH DAKOTA

### Buried valley traced in southeastern part of State

T. E. Kelly reported that test drilling in northwestern Barnes County revealed a buried glacial valley more than 30 miles long and locally more than 10 miles wide, concealed beneath morainic deposits. As much as 100 feet of water-bearing sand and gravel lies between the depths of 100 and 200 feet.

### Glacial deposits yield large water supplies near Bismarck

P. G. Randich reported that wells in Burleigh County yield as much as 1,000 gpm from glacial deposits filling preglacial drainage channels. The aquifers contain mostly melt-water sand and gravel, and are recharged from adjacent outwash deposits. The water contains considerable sodium, but the quality of the water improves gradually with continued pumping.

## WYOMING

### Natural gas in water from Fort Union Formation

According to T. R. Cummings, many water wells in Sheridan and Johnson Counties yield natural gas, particularly where coal or carbonaceous material occurs in the Tertiary Fort Union Formation. Some wells yield as much as 2 liters of gas per liter of water. Some flowing wells may flow by gaslift. The gas is principally methane, but it also contains some nitrogen, carbon dioxide, oxygen, and ethane, and trace amounts of propane and isobutane. Several possible sources may be postulated for the oxygen, nitrogen, ethane, and higher paraffin hydrocarbons, but the bulk of the methane, nitrogen, and carbon dioxide is thought to originate in coal or carbonaceous material.

### Reduced sediment loads in Wind River tributary

From study of sediment samples from Fivemile Creek, Fremont County, T. F. Hanly found that less sediment was transported during 1951–61 than formerly, even though annual runoff increased each year except the drought years 1960 and 1961. Channel-protection measures by the U.S. Bureau of Reclamation and the general absence of floods during 1951–61 seem to be the reasons for the reduced sediment load.

### Ground water for supplemental irrigation in Star Valley

According to E. H. Walker, considerable ground water from gravel is available in Star Valley for possible supplemental irrigation. Salty water at some places in the valley comes from solution of beds of rock salt in the Jurassic Preuss Sandstone.

### Stock water in northern Great Divide basin

C. E. Sloan's reconnaissance of the Seven Lakes Unit in the northern part of the Great Divide basin indicates that ample supplies of stock water can be developed from shallow depths in the alluvium of larger stream valleys and small closed basins. Wells in the upland areas generally obtain ample supplies at depths of 100 to 400 feet from bedrock formations of Eocene Age. Wells drilled on Battle Springs Flat to depths of 100 to 300 feet generally flow at the land surface.

### Ground water for Devils Tower National Monument

An investigation by H. A. Whitcomb and E. D. Gordon of the availability of ground water of suitable chemical quality for a public supply at Devils Tower National Monument resulted in the drilling of a deep test well to determine the quantity and quality of water that might be developed from the Minnelusa Formation (Pennsylvanian and Permian) and the underlying Pahasapa Limestone (Mississippian). As expected, water in the Minnelusa Formation was found to be too highly mineralized for domestic use. Drilling was continued until a cavernous zone was penetrated about 24 feet below the top of the Pahasapa, at a depth of 1,323 feet, and drilling was terminated in the cavernous limestone at a depth of 1,340 feet. The water in the Pahasapa Limestone is under sufficient artesian pressure to rise to within 21 feet below the land surface. Chemical analysis of the water shows it to be of the calcium sulfate type, very hard, and of only moderate mineralization for the area (533 ppm of dissolved solids). The water was judged acceptable by the National Park Service, and the well was completed in September 1962 as a public and domestic supply for the Monument.

## SOUTH DAKOTA

### Water from pre-Cretaceous rocks in Black Hills area

According to C. F. Dyer and M. J. Ellis, the quality of water available from pre-Cretaceous aquifers in western South Dakota does not necessarily correspond to the depth of the aquifer below land surface. Near the Black Hills all pre-Cretaceous aquifers yield water containing less than 3,000 ppm total solids and, in some localities, may yield water containing less than 500 ppm total solids. In some parts of western South Dakota, deep aquifers yield better water than shallow ones. In Haakon, Jackson, Jones, and Stanley Counties, carbonate rocks of the Mississippian Madison Group, probably the Mission Canyon Limestone, yield water that contains several hundred to 1,000 ppm less total solids than water from the stratigraphically higher Cretaceous Inyan Kara Group. In some localities the Madison Group yields water of better quality than that obtained from the overlying Minnelusa Formation of Pennsylvanian age.

### Artesian-head decline in Dakota Sandstone

The head of artesian water in the Dakota Sandstone in 21 counties in southeastern South Dakota declined 0.5 to 1.5 feet a year during the period 1958–62. According to C. F. Dyer and A. J. Goehring, no regional pattern of total decline or rate of decline has been noticed and the head has risen slightly in a few observation wells. In general, areas of flowing artesian wells have shown the largest decline in head.

### Shallow aquifers on Pine Ridge Indian Reservation

Ground water in sufficient quantities for domestic and livestock requirements is, according to M. J. Ellis, available from five shallow aquifers throughout the Pine Ridge Indian Reservation, except in areas along the western and northwestern boundaries where the Pierre Shale is exposed at the surface. Wells to the Arikaree Formation, the most extensive and commonly used aquifer, range from 100 to 450 feet in depth and yield moderate amounts of good quality water.

### Ground-water storage in Lake Madison area

M. J. Ellis and D. G. Adolphson found that outwash deposits in the Skunk Creek–Lake Madison drainage basin apparently are not hydraulically connected except by surface flow and may act as three separate aquifers. The northern aquifer, which contained an estimated 74,000 acre-feet of ground water in storage in 1962, is separated from the middle aquifer by terminal-moraine deposits. The middle aquifer, which contained an estimated 48,000 acre-feet of ground water in 1962, is separated from the southern aquifer by a high in the Precambrian surface. The southern aquifer contained an estimated 45,000 acre-feet of ground water in 1962.

Concentrations of sodium and boron in the three aquifers are low enough that the water is satisfactory for irrigation. The water has a medium to high salinity hazard and should be used only on soils having good drainage or on plants having moderate to good salt tolerance.

### Glacial-drift aquifers in Sanborn County

L. W. Howells[32] reports that more than 370 square miles of Sanborn County is underlain by glacial-drift aquifers that contain 10 feet or more of saturated sand and gravel. Aquifer tests disclosed that the coefficients of transmissibility in the major glacial-drift aquifers ranged from 25,000 to 230,000 gpd per ft.

The uppermost and most widely developed bedrock aquifer, the Niobrara–Codell aquifer, comprises a permeable zone near the base of the Niobrara Formation and the top of the Codell Sandstone Member of the Carlile Shale. Geochemical and drilling data indicate that the Niobrara–Codell receives recharge from the Dakota Formation in or near southeastern Sanborn County, and that it discharges water to and receives recharge from overlying glacial outwash deposits in northwestern Sanborn County. The Niobrara–Codell aquifer yields soft to moderately hard saline water that has a high boron content.

[32] Steece, F. V., and Howells, L. W., 1963, Geology and ground-water resources of Sanborn County, South Dakota with a section on magnetic anomalies by B. C. Petsch and a section on quality of water by R. L. Kilzer: South Dakota Geol. Survey Bull. 16.

### Shallow outwash deposits in Beadle County

Shallow glacial-outwash aquifers 25 feet or more thick may underlie as much as 500 square miles in Beadle County, according to L. W. Howells, J. C. Stephens, and L. S. Hedges. An additional 250 square miles in the county may be underlain by shallow aquifers ranging in thickness from 10 to 25 feet. Much of the water in the outwash aquifers is of borderline quality for irrigation.

The Cretaceous Pierre Shale is exposed at several localities in eastern and southwesternBeadle County, and underlies the glacial drift in all but the central and south-central parts of the county, where the drift is underlain by the Cretaceous Niobrara Formation. A buried valley in northern Beadle County is eroded as much as 200 feet below the general bedrock surface and locally may cut entirely through the Niobrara into the underlying Cretaceous Carlile Shale. The material filling the valley generally is fine grained and has low permeability, but locally it yields sufficient water for irrigation wells.

Although earlier studies showed that preglacial drainage was southward through Beadle County, preliminary data from the current study indicate that major drainage was northward.

## NEBRASKA

### Large yields from wells in Nemaha River valley

According to C. F. Keech, a study of Richardson County indicates that yields of as much as 650 to 1,000 gpm are obtainable in a small area immediately northwest of the town of Rulo and in the Nemaha River valley south of Rulo and east of Falls City. In most parts of the county, particularly in upland areas, few wells yield as much as 100 gpm.

### Water of Platte River suitable for irrigation

According to S. C. Downs, 3 years (1959–61 water years) of record indicates that water planned for diversion from the Platte River near Overton, Nebr., is of good quality for irrigaton in the Mid-State Reclamation District. Dissolved solids ranged from 350 to 800 ppm and averaged about 550 ppm. The water is of the calcium bicarbonate type and has no residual sodium carbonate. The average values are 785 micromhos per centimeter at 25°C. for specific conductance, 34 for percent sodium, 1.8 for sodium-adsorption ratio, and 0.13 ppm for boron content.

Ground water throughout the district also is of the calcium bicarbonate type. Dissolved solids range from 196 to 1,280 ppm. Generally, water from wells less than 60 feet deep has a greater dissolved-solids content than water from wells 60 to 200 feet deep. Observations in the fall indicate annual changes in dissolved-solids content of as much as 30 percent for water from some wells.

## UTAH

### Thick water-bearing deposits in Sevier River basin

According to C. H. Carpenter and L. J. Bjorklund, test drilling in the upper Sevier River valley revealed that the valley fill ranges in proven maximum thickness from 100 to more than 800 feet, is mostly saturated, contains many highly permeable zones, and contains ground water that is fresh and potable. Several valleys in the basin are about 6 to 40 miles long and about 1 to 5 miles wide. Ground water in these valleys occurs under both water-table and artesian conditions, and most of the valleys are drained by effluent streams.

Another test-drilling program, in the central Sevier River valley, indicated to R. A. Young and C. H. Carpenter, that the valley fill generally is more than 800 feet thick, is mostly saturated, contains many highly permeable zones, and that most of the ground water is fresh and potable. The valley fill is about 80 miles long, about 1 to 8 miles wide, and consists of 5 segments, each of which is an individual ground-water reservoir having water-table conditions in the upstream and lateral parts and artesian conditions in the downstream and middle parts.

### Interconnection of aquifers in Sevier Desert

R. W. Mower reports that a shallow and a deep artesian aquifer beneath the Sevier Desert are separated by a "confining" bed that is five times thicker near the flanking mountains than it is near the middle of the desert. No hydraulic connection between the two aquifers is apparent where the confining bed is thick, but where it is thin, about 8 miles north-northwest of Delta, pumping from either aquifer affects water levels in the other.

### Mineral content of ground water increasing in Pavant Valley

R. W. Mower also found that the concentration of dissolved minerals in ground water in the southern part of Pavant Valley is increasing, owing to the transpiration of water by irrigated plants and evaporation from irrigated land. Recharge from irrigation is only about half the water pumped, and small amounts of water leave the aquifer as underflow, the only natural discharge. Accordingly, the amount of ground water in storage is diminishing.

### Municipal and industrial supplies in upper Price River valley

Considerable artesian water for municipal and industrial use is available in the upper Price River valley in Utah and Carbon Counties according to R. M. Cordova. The water comes from the North Horn Formation (Cretaceous and Tertiary) and the Flagstaff Limestone (Tertiary), which have an estimated combined transmissibility of 50,000 gpd per ft. Movement of water is controlled by a small, shallow faulted syncline.

### Water levels declining in Tooele Valley

Water levels declined as much as 12 feet in the Tooele Valley during the 1962 irrigation season, according to J. D. Gates; the maximum decline was in areas of concentrated pumped or flowing wells. Several pumping tests in the areas of greatest yield indicated transmissibilities from 10,000 to 1 million gpd per ft.

### Quality of fish-hatchery water supplies

The chemical characteristics of water used in 11 fish hatcheries in Utah were studied by C. G. Mitchell. Water supplies of most hatcheries in the State contain 150–250 ppm of dissolved solids, have a hardness of 100–250 ppm (as $CaCO_3$), and are of the calcium bicarbonate type. The water used in 3 of the 11 hatcheries is of the calcium sulfate type and has a hardness of 250–650 ppm. These waters commonly are more highly mineralized and contain from 300 to as much as 950 ppm of dissolved solids.

### Winter runoff low in 1962–63

After a series of dry winters, Utah received in the winter of 1961–62 one of the best snow crops in a decade, according to G. L. Whitaker. The mean discharges for water year 1961–62 at practically all stream-gaging stations were the greatest since 1952. However, a severe drought began during the summer of 1962 and lasted until February 1963. Runoff during October through December 1962 was very little greater at most gaging stations and actually less at some stations than for the same period in 1961—the second driest year of record. Water in storage as soil moisture and ground water is low, and thus considerable precipitation will be needed to replenish these deficiencies before normal streamflow will be resumed.

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## COLORADO

### Possibilities of water salvage in Arkansas River

Studies by C. T. Jenkins, E. A. Moulder, and R. H. Langford of the hydrology of the Arkansas River in southeastern Colorado indicate that most water shortages during the last 20 years have been due to seasonal variations rather than to deficient yearly supply. A trend of increased consumptive use of water is explained as due in part to increasing use of ground water. They conclude that ground-water draft can be further increased without adverse effect. Substantial amounts of water could be salvaged by elimination of phreatophytes and by replacement of inefficient shallow offstream surface reservoirs with ground-water storage.

### Ground-water supplies near Boulder

Small supplies of ground water are available near Boulder from two main sources: the sandstone beds of the Cretaceous Laramie and Fox Hills Formations, and the alluvium of major creeks. Depths of wells in the sandstone beds range from 50 to 800 feet, and some wells yield as much as 70 gpm; however, yields ranging from 5 to 20 gpm are more common. Depths of wells in the alluvium range from 10 to 40 feet, and conventional wells in the alluvium of Boulder, South Boulder, Coal, and Left Hand Creeks yield as much as 50 to 200 gpm, but yields from 5 to 25 gpm are more common.

### Water use in lower Cache la Poudre basin

About 70,000 acre-feet of water is pumped annually from 1,100 irrigation wells in the lower Cache la Poudre River basin of north-central Colorado, according to L. A. Hershey and P. A. Schneider, Jr. Wells tapping Pleistocene valley fill yield 50 to 2,000 gpm. Approximately 900,000 acre-feet of water is available annually to the area through precipitation (500,000 acre-feet), natural streamflow (250,000 acre-feet), and transmountain diversion (150,000 acre-feet). Most of the 500,000 acres in the area is devoted to agriculture, and about 250,000 acres is irrigated. Ground water is used as a supplemental supply on about 70,000 acres. About 65,000 acre-feet leaves the area as surface flow and 5,800 acre-feet as ground-water outflow.

About 700,000 acre-feet of ground water is in storage in the valley fill, and about 100,000 acre-feet discharges annually from the valley fill to the Cache la Poudre River. Water from the valley fill generally contains large amounts of dissolved solids, principally calcium bicarbonate and sulfate. Domestic and stock wells obtain sodium bicarbonate water of better quality from the Upper Cretaceous Fox Hills Sandstone and Laramie Formation, which underlie the eastern two-thirds of the area.

### Base exchange in artesian water near Grand Junction

In the Grand Junction area, S. W. Lohman (1–62) found a nearly linear decrease in hardness of artesian water in the Jurassic Entrada Sandstone, with increased, distance basinward from the outcrop. This resulted from natural softening by base exchange between the water and clay minerals in the sandstone.

### Ground-water supplies in Rocky Mountain National Park

Terrace deposits of the North Fork of the Colorado River, in the western part of Rocky Mountain National Park, are at least 84 feet thick and are capable of yielding moderate quantities of water to wells, according to P. T. Voegeli, Sr. Surficial deposits in the 50-square-mile drainage area above the mouth of the North Fork discharge 500 to 600 acre-feet of water per month to the river during low flow.

### Gound-water supplies in Otero and Crowley Counties

Approximately 760,000 acre-feet of water could be developed annually from unconsolidated aquifers in Otero and southern Crowley Counties, Colo., according to W. G. Weist, Jr., and E. D. Jenkins. They estimate further that 200,000 acre-feet could be developed from consolidated artesian aquifers in the area. About 60,000 acre-feet was withdrawn by pumping for all purposes in 1962. Along the Arkansas River valley in this area, nearly 270,000 acre-feet is diverted from the river, and another 40,000 acre-feet is pumped for irrigation. About 26 percent of this water becomes available for reuse either through seepage and return streamflow or by pumping.

## KANSAS

### Ground water in unconsolidated deposits contaminated by brines

C. K. Bayne (1–62) reports nearly 250,000 acre-feet of water in storage in alluvium and Pleistocene terrace deposits in Crowley County. Most of this is in terrace deposits of Wisconsin age and Recent alluvium which have been polluted by oil-field brines and natural brines from underlying Permian rocks. The brines are more concentrated near the base of the aquifers, and move downstream at a rate of about a quarter mile per year. Several supply wells for the city of Winfield have been abandoned because of high brine concentration. It was suggested that a horizontal well be constructed in the upper part of the aquifer so as to skim off the fresh water without getting any of the deeper, heavier salt water.

### Ground-water levels declining in Grant and Stanton Counties, Kans.

From comparison of 1939–42 and 1960 water-table contour maps, S. W. Fader, E. D. Gutentag, D. H. Lobmeyer, and W. R. Meyer found that the weighted-average water level in Grant and Stanton Counties in western Kansas had declined 7.8 feet. The maps also indicated that (1) about 60 mgd of ground water was flowing into the area from the west and about 90 mgd was flowing eastward from the area; (2) pumping for irrigation between 1940 and 1960 had not appreciably changed the inflow and outflow rates during the 20-year period; and (3) recharge from precipitation probably was less than 10 percent of the 1959 pumpage; thus, about 90 percent of the water pumped came from storage. Using a computed apparent coefficient of storage of 0.32, it is estimated that the weighted average water level will decline about 1.2 feet per year at the 1959 pumping rate.

Fossils identified by E. D. Gutentag and other evidence indicate that the Pleistocene deposits in this area are 400 feet or more thick, a thickness considerably greater than that found by previous investigators on the basis of less adequate data.

### Surface storage for maintenance of streamflow

Records of streamflow at 113 sites in Kansas analyzed by L. W. Furness (1–62) show the opportunity of storing natural streamflow at these sites for release in time of drought. On the South Fork Ninnescah River near Murdock, where opportunities for sustained flow per square mile are better than elsewhere in Kansas, storage of 100 acre-feet per square mile of drainage area would provide sustained gross outflow of 0.20 cfs per sq mi with only 2 percent chance that the storage would be insufficient. However, on Cow Creek near Lyons, only 50 miles away, the comparable outflow would be only 0.032 cfs per sq mi.

### Ground water in storage in Wallace County

W. G. Hodson reports about 4 million acre-feet of ground water in storage in the Ogallala Formation in Wallace County, mostly in the southern part. The Ogallala is as much as 400 feet thick, and as much as 280 feet is saturated. Aquifer tests of the Ogallala indicate transmissibilities of about 150,000 gpd per ft, and permeabilities of about 1,000 gpd per sq ft. Eastward movement of water was calculated to be about 0.9 foot per day, or about 1 mile in 16 years.

There were 86 irrigation wells in Wallace County in September 1958 and 96 irrigation wells in September 1960, an increase of about 12 percent in 2 years. Yields of most irrigation wells range from about 400 gpm to more than 2,000 gpm. About 20,000 acres of land were covered by ground-water rights, or applications for rights, as of July 1961. The authorized quantity of ground water appropriated was about 38,000 acre-feet.

## ARIZONA

### Supplemental water for Fort Huachuca

Wells supplying the Ft. Huachuca Military Reservation are pumping from a thin but productive aquifer, according to S. G. Brown (1–62) and F. Anderson. Pumping levels of wells in the aquifer are declining, but not rapidly as yet. An average of 2.4 mgd could be obtained from streams and springs in the Huachuca Mountains, and proper development of the springs would make even more water available. These sources, now largely wasted, could supply the reservation for 4 to 6 months each year, and any excess could then be used to recharge the aquifer.

### Little precipitation discharged from springs along Mogollon Rim

Reconnaissance of headwater springs in the Gila River drainage basin by J. H. Feth and J. D. Hem (3–63) indicates that only about 2 percent of the precipitation on the Mogollon Rim region appears as spring flow—the rest is discharged by evaporation and transpiration, by flash seasonal flow in largely ephemeral streams, or by subsurface movement out of the region. The springs examined yield water of good chemical quality except for a few that discharge thermal saline water in amounts sufficient to deteriorate the quality of water in both the Salt and Gila Rivers. Diversion of the relatively small volumes of more highly mineralized water, if feasible, would greatly improve the quality of water in the rivers without materially diminishing the quantities available for use.

### Rapid ground-water depletion in Willcox basin

The ground-water reservoir beneath the Willcox basin is being rapidly depleted, according to S. G. Brown, P. W. Johnson, L. R. Kister, and H. H. Schumann. In one heavily pumped area the water level has declined more than 120 feet since 1952. In 1962, 190,000 acre-feet of water was pumped to irrigate 71,000 acres; but estimated annual recharge is not more than 30,000 acre feet. Accordingly, increasing development will accelerate the already rapid decline in water level.

Analyses of more than 200 water samples from this area indicate that the concentration of fluoride averages more than 1.5 ppm and locally is as much as 27 ppm. The waters high in fluoride content are associated with Precambrian schist or Tertiary rhyolite or sediments derived from these rocks.

### Water levels decline sharply in lower Santa Cruz basin

According to W. E. Hardt, R. E. Cattany, and L. R. Kister, ground water in the lower Santa Cruz basin of northwestern Pinal County is being withdrawn from the alluvial aquifer at a much greater rate than the rate of recharge. Surface and ground-water inflow to the study area is estimated at less than 300,000 acre-feet per year, and the pumping rate at more than 1 million acre-feet per year. Average yearly water-level decline for the last 10–20 years has been about 3 feet in the Gila River area, 5 feet in the Casa Grande–Florence area, 6 feet in the Eloy area, and 10 feet in the Stanfield–Maricopa area.

Subsurface geologic interpretation of logs of about 2,000 wells permitted contouring the lower limit of permeable zones reached in drilling, and in delineating three permeable zones and an intervening silt and clay unit. Total recoverable water from storage above this lower limit, which is at a depth of about 800 feet, is estimated at about 44 million acre-feet.

## NEW MEXICO

### Estimated future water requirements of Albuquerque area

From basic assumptions of water requirements and aquifer characteristics, H. O. Reeder, L. J. Bjorklund, and G. A. Dinwiddie have computed that the greatest expected lowering of water level in the Albuquerque area from 1960 to 2000 will be 86 feet, about 6 miles east of the downtown area. The water level at this point declined almost 11 feet from 1920 to 1960. In a small area about 9 miles northwest of downtown Albuquerque, water levels declined little, if any, before 1960 but are expected to decline 34 feet from 1960 to 2000. Elsewhere, the lowering is expected to be less than these amounts, particularly near the Rio Grande.

The water table in Albuquerque, 5 to 8 miles east of the Rio Grande, will eventually be lower than the river, causing water to move eastward from the river.

From 1920 to 1960 about 80 percent of the water pumped was derived from the Rio Grande, either through decrease in discharge of ground water to the river or increase in underflow from the river, and from 1960 to 2000, 71 to 76 percent of the water will be derived from the river. From 1950 to 1960 an average of 46,000 acre-feet per year was pumped, of which 37,200 acre-feet was derived from the river; from 1990 to 2000 these amounts are expected to increase to 226,000 and 165,000 acre-feet, respectively.

## OKLAHOMA

### Thickness of fresh-water zone

Maps by D. L. Hart, Jr., show that in Oklahoma, fresh water extends to depths that range from 0 to more than 3,000 feet. The transition from fresh to saline water is sharp in many areas but is gradational in others. Fresh water circulates to greatest depths in limestone aquifers in the south-central and northeastern parts of the State. The base of the fresh-water zone is shallowest in western Oklahoma where the bedrock is Permian siltstone and shale.

### Ground-water supplies along Washita River

Alluvial deposits along the Washita River between Clinton and Anadarko are primarily fine-grained sand and clay averaging about 60 feet in thickness, according to D. L. Hart, Jr. Test drilling and pumping indicate that yields of 60 to 150 gpm could be developed in about half the valley and more than 150 gpm in about 10 percent of the valley. Wells of higher yield are restricted to a longitudinal section where the alluvial deposits are from 90 to 120 feet thick and coarser than elsewhere.

### Base flows in Beaver Creek basin

L. L. Laine (1–63) found small sustained base flows in the upper and lower parts of Beaver Creek basin, in southwestern Oklahoma, but no flows in the central part of the basin for at least 10 percent of the time, because of the channel losses.

### Permian aquifers in southwest Oklahoma fully developed

C. E. Steele and J. E. Barclay concluded that the ground-water supply of the cavernous aquifer in the Permian Blaine Gypsum and Dog Creek Shale in the southwestern corner of Oklahoma is fully developed. The aquifer supplies water to irrigate about 35,000 acres, and in normal years, pumpage for irrigation is about 50,000 acre-feet. Pumpage plus natural discharge is approximately equal to the average recharge.

### Low flows of good quality in Little River basin

R. P. Orth reports that during low-flow periods, surface waters in the Little River basin in southeastern Oklahoma are soft and low in dissolved-solids content, the specific conductance being generally less than 70 micromhos per centimeter at 25°C. The content of dissolved solids in streams leaving areas underlain by Pennsylvanian and Mississippian rocks increases nearly twofold after the streams enter areas underlain by the Cretaceous Paluxy Sand and by Devonian, Ordovician, and Cambrian rocks.

### Main aquifers in Woodward County

P. R. Wood indicates that in Woodward County, ground water sufficient for municipal, industrial, or irrigation supplies occurs chiefly in alluvial deposits along the North Canadian River valley and in the Tertiary Ogallala Formation in the southwestern part of the county. Dunes common to both areas facilitate replenishment to these aquifers. Permian redbeds that crop out in the northeastern part of the county and form the bedrock beneath the Tertiary and Quaternary deposits are poor aquifers and in most places yield insufficient water for irrigation.

### TEXAS

#### Surface water of Hubbard Creek basin affected by brine

C. H. Hembree and J. F. Blakey found that streams of the Hubbard Creek basin contain water of good quality having generally less than 50 ppm of chloride except where contaminated by oil-field brine. Many producing oil wells and improperly plugged dry holes release brine containing 24,000 ppm or more of chloride, much of which reaches Salt Prong Hubbard Creek from a small area near Albany.

#### Gains in base flow in upper part of Colorado River drainage

P. H. Holland, L. S. Hughes, and H. B. Mendieta found that the base flows of the Llano and Pedernales Rivers in the Colorado River basin increased throughout the reaches studied. On the Llano River, in a distance of 83 miles below Junction, Tex., it was found that the gains in base flow directly to the river channel were slightly in excess of all losses; therefore, all the large initial base flow originating above Junction (129 cfs) and inflow from tributaries (53 cfs) reached the lower end of the river at Llano. Dissolved solids in the Llano River range from 259 to 225 ppm, the lower concentrations apparently resulting from precipitation of calcium carbonate in the stream channel. In the Pedernales River basin, water containing as much as 700 ppm of dissolved solids is contributed by streams draining outcrops of the Hensell Sand Member of the Travis Peak Formation. Dilution by water of lower concentration from tributaries draining areas underlain by the Ellenburger Group resulted in a concentration of only 288 ppm dissolved solids in the Pedernales River at the head of Lake Travis.

#### Quality of the Sabine River

L. S. Hughes and D. K. Leifeste found that the water of the Sabine River and most of its principal tributaries in Texas and Louisiana is of excellent quality for potential use by municipalities and industries. Of 33 tributaries sampled, only one, Lake Fork Creek, occasionally had dissolved-solids concentrations exceeding 500 ppm. Other streams usually contained less than 200 ppm dissolved solids, and concentrations as low as 40 ppm frequently were observed in flood flows. The Sabine River near Ruliff contained less than 200 ppm more than 90 percent of the time.

#### Ground-water storage in Refugio County

C. C. Mason (1–63) estimated that on the order of 10 to 20 million acre-feet of ground water containing less than 300 ppm chloride and 1,000 ppm dissolved solids is in storage in Refugio County, principally in the northwestern third of the county. The maximum potential rate of withdrawal of ground water containing less than 300 ppm chloride is about 42,000 acre-feet a year. It seems probable, therefore, that the predicted future needs of more than 11,000 acre-feet a year for industry and public supply can be obtained safely from wells.

#### Saline ground water complicates water supply in Beaumont area

The transmissibility of the water-bearing sand beds in Orange County ranges from 100,000 to more than 400,000 gpd per ft., according to J. B. Wesselman. However, in the southern and southwestern parts of the county, the sand beds contain salty water. Locally a clay bed underlying the lowermost fresh-water sand is absent and heavy pumping may cause salty water to move upward into the fresh-water zone.

## *PACIFIC COAST AREA*

There is an extreme diversity of hydrologic and climatic conditions in the Pacific coast area, which in this discussion includes the States of Alaska, Washington, Oregon, Idaho, Nevada, California, and Hawaii. The physiographic and geologic environment is particularly complex, and thus the contrasts in the natural environment and in hydrologic phenomena are pronounced. The extremes range from the barren deserts of southern California and Nevada to the lush Olympic Peninsula of Washington to the Arctic wastes of northern Alaska. Superimposed on this diverse pattern is the increasing complexity of the cultural setting. With the booming population and industrial expansion of the West, competition for water supplies grows keener by the year.

Virtually every conceivable water problem confronts the developers and users of water in this region. The major problems include inadequacy of natural supply, maldistribution and variability of the resource, inferior quality (chemical and physical) of natural water, pollution, water loss, floods, and droughts. Thus, effective utilization through appropriate conservation and management is a prime consideration with many legal implications.

Investigations of the U.S. Geological Survey in the Pacific Coast area are directed toward studies that will aid in the resolution of these water problems. Studies of water occurrence and availability in time and in place provide the basis for developing and managing the natural supply. Particularly pertinent are investigations of underground and surface supplies where maldistribution of the supply exists and where a quantitative judgement is necessary for meeting water demands. The total supply is being evaluated to provide a basis for determining the economic feasibility of exporting water from areas of surplus to areas of deficiency. Seasonal runoff in streams and recharge to aquifers are extremely varied and are being investigated throughout the area. Study of sustained yield of wells, together with the evaluation of movement and availability of ground-water in underground reservoirs, is another continuing segment of the program.

## ALASKA

The problems of water as an economic resource in Alaska relate largely to development and maintenance of water supplies in the rigorous northern climate. Surface-water supplies, which are abundant in most of Alaska, offer special problems owing to winter freezing, and ground water in many areas has advantages as an alternate or supplemental supply. In arctic Alaska, where the ground is frozen to great depths, obtaining any winter water supply at reasonable cost becomes a major problem. Some aspects of this are discussed under Permafrost (p. A173). Other water problems of particular importance in Alaska are floods and hydroelectric power development.

The Geological Survey conducts investigations of the occurrence, availability, and quality of surface and underground waters, and determines sediment discharge on selected streams in Alaska. The program includes a hydrologic network covering portions of the State. Flood-frequency studies, determination of hydrologic and hydraulic characteristics of streams at selected sites, and evaluation of waterpower potential are in progress.

### Ground-water use increases at Anchorage

Studies by D. J. Cederstrom, F. W. Trainer, and R. M. Waller (1–62) in the Anchorage area show that large quantities of good water are available from interconnected artesian aquifers in at least three complex units of glacial drift. Under nonpumping conditions about 5 mgd flows seaward through each mile-wide section of the drift. Well yields up to 2,600 gpm were reported.

R. M. Waller found that average ground-water use in the Anchorage area increased to over 5 mgd in 1961 to supplement the 7.9 mgd average use of surface water. However, no significant change in ground-water storage was noted. Ground-water use decreased slightly in 1962. Sea-water encroachment has not been noted in periodic samples of coastal wells, but the presence of a saline-water aquifer beneath the fresh-water aquifer was discovered in 1962 on Fire Island, just off the Anchorage mainland.

## PACIFIC NORTHWEST

Diversified hydrologic investigations are in progress in the Pacific Northwest in Washington, Oregon, and Idaho, including most of the drainage basin of the Columbia River and its major tributaries, the Snake and Willamette. Some of the most pressing problems involve obtaining sufficient water to supply cities and industries; availability of water for irrigation in the dry areas east of the Cascade Range; interrelations of ground and surface waters, especially in the volcanic rocks of the Columbia Plateau; and the most effective development of the Columbia River. The programs include studies of the occurrence, availability, and quality of surface and underground waters and the sediment discharge of streams. An extensive hydrologic network throughout the Pacific Northwest provides continuing basic data. Significant findings of studies in progress or completed during the year in this region are summarized below. Studies are in progress also in each State to determine the flood frequency and related hydrologic and hydraulic characteristics of streams at selected sites.

### Ample water for future growth in Pacific Northwest

A study now nearing completion, under the direction of G. L. Bodhaine, seeks to describe and analyze historic and present characteristics of the water resources of the Pacific Northwest and to forecast the future role of water in determining the economic destiny of the region. Water-supply conditions and water demands will be forecast by regional subareas in 5-year increments to 1985, with trends projected to 2010. A preliminary appraisal of the water-supply situation indicates that the Pacific Northwest, as a whole, has enough water to support the projected growth and economy. The key to its effective utilization will be the wise management of the facilities for storage, distribution, and use of the resource.

### Subsurface water losses from Cedar River to Snoqualmie River

Preliminary investigations by F. T. Hidaka show a loss of water from the Cedar River basin in western Washington, southeast of Seattle, averaging about 60 to 70 cfs as a result of the construction of Chester Morse Lake dam. The raising of the water levels behind this dam and another masonry dam on the river a short distance downstream has induced underground seepage from Chester Morse Lake to the adjacent South Fork Snoqualmie River basin.

### Effect of logging on streamflow in western Washington

Logging in as much as 6 percent of the drainage area per year of Snow Creek basin in western Washington has had no apparent effect on runoff. Donald Richardson notes that runoff comparisons with adjacent unlogged basins in the Upper Green River basin for the period 1946–61 show no significant effect of logging on the rate or volume of runoff.

**Expansion of ground-water supplies at Tacoma**

In a study of the ground-water resources in the vicinity of Tacoma, K. L. Walters (1–63) found the municipal well field to be in an area underlain by glacial aquifers whose permeability may be the greatest of any in the Puget Sound lowland. The well field is located in a channel formed by a stream that discharged from a glacial lake and laid down coarse clean gravel. Pumping from the field started in 1903, but has had intensive development since 1929. Currently 13 public-supply wells produce from 51 to 64 mgd. While the field is used intermittently to supplement surface supplies, it serves as a reliable emergency supply for Tacoma, and production could be increased substantially without serious depletion.

**Ground-water levels continue to rise in parts of Columbia Basin Irrigation Project**

Studies by M. J. Grolier and J. W. Bingham (see also p. A95) show that water levels in many places in the Columbia Basin Irrigation Project rose more than 100 feet between 1952 and 1958 as a result of irrigation. The changes exceeded 250 feet in a 6-square-mile area west of Quincy, Wash.; the greatest rise observed was 286 feet. Between 1940 and 1952 the water levels in this same area declined more than 50 feet due to excessive ground-water pumping for irrigation prior to completion of the Columbia Basin Irrigation Project canals.

The largest area in which the rises exceeded 100 feet extends over 100 square miles in the Winchester–Quincy–George area. Other large areas with similar rises by 1958 are the Moses Lake–Wheeler–Lind Coulee area, and the north side of the Saddle Mountains from Taunton Terrace eastward to parts of the Othello Channels. Although the Saddle Mountains, the surface expression of an anticline in basalt, are a topographic divide, they are not a barrier to ground-water movement near their east end, south of Othello. A well south of the anticline and 2½ miles from irrigated canals and wasteways on the north side has shown a continuous rise of more than 40 feet in water level in 5 years; by 1961 the water levels had risen about 100 feet.

**Quality of ground water affected by irrigation in Columbia Basin Irrigation Project**

The chemical quality of ground water in the Columbia Basin Irrigation Project area of east-central Washington shows significant vertical and areal variation, according to A. S. Van Denburgh. Water from deep (500–1,000 feet) basalt aquifers that are not affected by percolating irrigation water is distinctive in chemical character. Silica, sodium, and bicarbonate are the principal constituents, and concentrations of potassium and fluoride (as much as 25 and 2.5 ppm respectively) commonly are greater than in most ground water of the Pacific Northwest. Shallow to moderately deep (100–500 feet) basalt aquifers in irrigated areas contain ground water of a different chemical type; the principal constituents are calcium, magnesium, bicarbonate, sulfate, and chloride. Nitrate also is an important constituent of this ground water in several areas, and concentrations greater than 50 ppm are not unusual.

**Precision of estimates of storage behind Grand Coulee Dam**

E. G. Nassar has determined that instantaneous water-level changes of Franklin D. Roosevelt Lake, impounded by Grand Coulee Dam, have varied as much as 0.66, 0.26, and 0.36 feet, respectively, at low, medium, and high discharges. These variations occurred in the upper 5 feet of reservoir stage in the 1952–58 period as a result of severe windstorms and changes in atmospheric pressure. Estimates of storage content based on stages at Grand Coulee Dam could be in error as much as 14,200, 7,600 and 6,300 acre-feet, respectively, the largest representing about 0.3 percent of the live-storage contents.

**Potential effect on ground water of raising American Falls Dam**

M. J. Mundorff reports that the capacity of the American Falls Reservoir in southeastern Idaho could be increased from 1.7 million to 3 million acre-feet by raising the dam 20 feet. Computations based on the transmissibility of the aquifer, increased gradient of the ground water, and probable width of the aquifer involved indicate that ground-water outflow would increase about 10 to 15 cubic feet per second and that the average seepage loss after reservoir enlargement would be on the order of 70 cfs.

**Sources of inflow to Spokane River**

In an investigation of large ground-water discharges to the Spokane River in the reach from near the Idaho-Washington State line to some distance below Spokane, C. A. Thomas (1–63) reports that the total inflow to the aquifers above Spokane averaged about 1,200 cfs during 1959 and 1,100 cfs during 1951–59. The total ground-water inflow to Spokane River averaged 1,450 cfs during 1959 and also during 1951–59. By far the largest part of the effluent seepage is generated in the Spokane River watershed itself. This contradicts assumptions of earlier investigators who concluded that the largest single source of the ground-water inflow is seepage from Pend Oreille Lake.

### Ground-water discharge in the Ahtanum Valley

Ground-water inflow increases surface flow appreciably in the Ahtanum Valley, Yakima River basin, Washington. B. L. Foxworthy [33] estimates that seepage discharge to the Yakima River from this valley may range from about 20,000 to 25,000 acre-feet per year. The consumptive waste of ground water by phreatophytes probably exceeds 4,000 acre-feet per year.

### Surface-water quality in Lower Columbia River Basin

On the basis of a reconnaissance study of streams in the Lower Columbia River basin, J. F. Santos reports that most are calcium magnesium bicarbonate waters. Headwater reaches of streams in the Cascade and Coast Ranges contribute waters containing less than 100 ppm dissolved solids. Streams draining arid areas or traversing irrigated tracts are considerably higher in mineral content. A salt-balance problem was noted in the Hermiston–Stanfield area in Oregon. Pollution by sewage has reached undesirable levels in the Walla Walla River, the Willamette River from Eugene to Portland, and the Columbia River from Portland to Puget Island.

### Mean monthly temperatures for Oregon streams

A. M. Moore finds that spot observations of water temperature at streamflow measurement stations, collected since 1946, can be combined to give reliable estimates of the mean-monthly water temperature of Oregon streams; estimates of monthly range in temperature are less reliable. The mean monthly temperatures can be refined further by correlation with continuous records of water temperature obtained at other stations. These correlations are generally excellent, with standard errors of 1° or 2°F.

### Deterioration of ground-water quality in Snake River Plain

Quality of ground water has deteriorated significantly in the last 50 years in the southern part of the basalt aquifer of the Snake River Plain, Idaho, as a result of drainage from irrigated lands. E. H. Walker reports that in a 2,000-square-mile area—a quarter of the total area of the aquifer—the dissolved-solids content is at least 50 ppm (parts per million) higher than the original concentration of about 200 ppm, and in some places the ground water now contains from 400 to 600 ppm of dissolved solids. Further change in the water quality can be expected with the increase in the amount of ground water pumped for irrigation.

[33] Foxworthy, B. L., 1962, Geology and ground-water resources of Ahtanum Valley, Yakima County, Washington: U.S. Geol. Survey Water-Supply Paper 1598, 100 p.

### Ground-water use in Willamette Valley

Use of ground water for irrigation in the highly productive French Prairie area of the northern Willamette Valley, Oreg., has increased nearly 10-fold in the last 20 years, according to Don Price, who concludes that sufficient water of good chemical quality can be developed to irrigate all arable land in the area as well as to supply other demands for ground water. Optimum development of the ground water will require (a) proper construction of wells to yield sand-free water in areas underlain by poorly sorted alluvium and fine-grained lacustrine deposits, and (b) proper spacing of wells to minimize local overdraft and well interference.

On the east side of the northern Willamette Valley, in the Molalla-Salem Slope area, the use of ground water for irrigation and for municipal and rural water supplies is increasing rapidly. Many wells drilled show unexpectedly low yield or undesirable chemical quality. E. R. Hampton has found that varied, semi-isolated bodies of basalt of Miocene age distributed discontinuously on the east side of the valley constitute some of the most productive aquifers. Marine sandstone and volcanic rocks of early Tertiary age generally yield saline water to wells tapping them at considerable depth; marine sandstone at shallower depth, where it has been flushed of saline water, may yield as much as 100 gpm of good-quality water to wells. Ground-water development based on recognition of the geologic controls and adequate well construction probably would provide enough water for irrigation of most of the irrigable land in the lower part of the area.

### Ground-water potential in East Portland area

The amount of ground water used each year in the eastern part of Portland, Oreg., and adjacent suburban and rural districts is much less than the available supplies. G. M. Hogenson (1–62) found that the principal aquifers are gravel and sand beds in alluvial stream deposits that underlie the flood plains of the Columbia and Willamette Rivers. The amount of ground water used in the area in 1960 was nearly 50,000 acre-feet, only a small part of the amount that is replenished naturally each year. Present trends of development and population growth in the area indicate that future withdrawals for all purposes will be substantially greater.

### Basalts of Snake River Plain yield more water than Columbia River Basalt

E. H. Walker reports that the Pleistocene basalt of the Snake River Plain of southern Idaho yields far more water to wells than the Miocene Columbia River Basalt of Washington, Oregon, and western Idaho. On the average, the basalts of the Snake River Plain yield a little more than 1,000 gpm per foot of drawdown to wells that penetrate 100 feet below water level, whereas the average yield from similar wells tapping the Columbia River Basalt is no more than 5 gpm per foot of drawdown. The water-bearing openings in the Miocene Columbia River Basalt were originally smaller and fewer than those in the basalts of the Snake River Group, and the differences have been accentuated by weathering and deformation which have affected the Columbia River Basalt considerably and the younger basalts of the Snake River Plain very little.

#### Little ground water for irrigation in western Saylor Creek area, Idaho

E. G. Crosthwaite (2–62) found that in much of the Saylor Creek area, Idaho, depths to water are too great and yields of some aquifers are too small to warrant development of ground water for irrigation. In the eastern part of the area, however, nine wells obtained sufficient water for irrigation from aquifers at moderate depth in the Idavada Volcanics of Pliocene age.

#### High artesian head in Weiser River basin

Results of studies by E. H. Walker and H. G. Sisco (2–63) show that the Columbia River Basalt is the most productive water-bearing unit in the lowlands of the Weiser River basin in southwestern Idaho. Recent drilling has revealed artesian pressures that locally raise water 150 feet above land surface, the highest pressures yet known in Idaho.

#### Ground water in glacial outwash in northern Idaho

In the valleys of the Sandpoint region of northern Idaho, ground-water supplies adequate for irrigation and for towns and industries are found only in areas underlain by glacial outwash gravels rather than by lake-bed sediments, according to E. H. Walker (1–63). Thick water-bearing sand and gravel deposits were found only in the Hoodoo Valley and the valley south of Cocolalla Lake. The other lowlands are underlain mainly by lake beds, in which beds of sand and gravel are few and thin.

#### Irrigation would change hydrologic regime of Dry Lake area

Proposed irrigation of the Dry Lake area southwest of Boise, Idaho, would cause many changes in the ground water regimen, according to P. R. Stevens. Yearly recharge of ground water under project operation is conservatively estimated at about 40,000 acre-feet. This recharge would raise the water table and lower the pumping lifts, but the ground-water divide would shift to the south or southwest, and existing drainage problems south of Melba and west of the Dry Lake area would be further complicated. Drainage problems due to high water table are unlikely in the Dry Lake area.

#### Ground water in the Camas Prairie

Computations by W. C. Walton (1–62) suggest that 12,000 acre-feet of ground water might be withdrawn annually from the Camas Prairie, Camas and Elmore Counties, Idaho. The principal aquifers are sand and gravel, and basalt. Water in the shallow deposits is not confined, whereas water in the deeper deposits occurs chiefly in two artesian aquifers.

### NEVADA

In Nevada the principal water problems are availability of surface and ground water for irrigation, municipal, and industrial supplies. Floods also are a serious problem because of the flash flows of streams in arid climates. A continuing appraisal of flood characteristics of Nevada streams aids in highway planning and bridge design. Particular attention is being directed to a reconnaissance evaluation of ground-water potential in the desert valleys in the State.

#### Estimates of ground-water yield in undeveloped desert basins

Statewide ground-water reconnaissance studies in Nevada by T. E. Eakin, W. C. Sinclair, G. T. Malmberg, and G. E. Walker provided preliminary estimates of perennial yield for 10 ground-water basins. According to Nevada ground-water law, if depletion of a ground-water basin is imminent, the State Engineer is empowered to establish necessary regulatory measures for control of the ground-water basin for sound conservation and the best interests of the public welfare. Initial development of ground-water basins in recent years commonly has occurred so rapidly that depletion has occurred before detailed studies could be completed. The preliminary estimates of perennial yield, which provide a management guide, are evaluated from estimates of natural recharge to and discharge from particular ground-water basins.

Preliminary estimates of perennial yield for nine of the ground-water basins studied are: 5,000 acre-feet in Gabbs Valley, Washoe County;[34] 3,500 acre-feet in Sarcobatus Flat, Nye and Esmeralda Counties, and 2,000 acre-feet in Oasis Valley, Nye County (Malmberg and Eakin, 3–62); 4,000 acre-feet in Hualapai Flat, Pershing and Humboldt Counties (Sinclair, 1–62); 2,500 acre-feet in Ralston Valley and 2,000 acre-feet in Stonecabin Valley, Nye County (Eakin, 2–62); 24,000 acre-feet in Amargosa Desert, Nye County, Nev., and Inyo County, Calif. (Walker and Eakin, 1–63); 10,000

[34] Eakin, T. E., 1963, Ground-water appraisal of Gabbs Valley, Mineral and Nye Counties, Nevada: Nevada Dept. Conservation and Nat. Resources Recon. Rept. 9.

acre-feet in the Long Valley-Massacre Lake region, Washoe County; and 7,500 acre-feet in Duck Lake Valley, Washoe County.[35]

### Interbasin movement of ground water

The reconnaissance investigations in some valleys indicated that estimated annual recharge and discharge for the individual valleys were not in balance. T. E. Eakin (1–62) concluded, for example, that most of the estimated 14,000 acre-feet of annual ground-water recharge from precipitation in Cave Valley discharged by underflow through Paleozoic carbonate rocks to the adjacent White River valley southwest and south of Cave Valley. The hydraulic gradient and the small amount of ground water discharged by evapotranspiration from Cave Valley appear to support this thesis. Similarly, a considerable amount of the ground water discharged from Ralston and Stonecabin Valleys is estimated by Eakin (2–62) to move as underflow through bedrock to valleys to the south and southwest.

Walker and Eakin (1–63) estimate that the average annual discharge of about 24,000 acre-feet of ground water in the Amargosa Desert far exceeds the recharge from precipitation within the 2,600-square mile surficial tributary area. About 17,000 acre-feet of this total discharges from springs in Ash Meadows located near outcrops of Paleozoic carbonate rocks. Devils Hole, near the springs, is the surface expression of an extensive solution system in these Paleozoic carbonate rocks. Presumably this ground-water discharge is derived from the Spring Mountains, Pahrump Valley, and the Nevada Test Site and moves by underflow through Paleozoic carbonate rocks.

G. T. Malmberg estimates that the average annual natural recharge to Pahrump Valley, Nevada–California, exceeds the average annual natural discharge by approximately 13,000 acre-feet. The apparent imbalance is considered due to ground-water underflow through predominantly carbonate rocks of Paleozoic age that form the bulk of the indurated rocks underlying the valley fill and that crop out in the bordering mountains. Most of the ground-water underflow is assumed to be discharged by springs in the Ash Meadows area, beyond a topographic divide in the Amargosa Desert.

### Water resources of Long Valley–Massacre Lake area

W. C. Sinclair reports that the water resources of the Long Valley–Massacre Lake region, Nevada, are more than adequate to support the agricultural development which the climatic factors and soil conditions will permit. Although much of the region is underlain by volcanic rocks, including basalt, the bedrock apparently is much less permeable than similar flow rocks in the Snake River Plain region to the north. The most important sources of ground water in the area are the sand and gravel aquifers buried within the less permeable deposits of the valley fill.

### Evapotranspiration decreases flow of Humboldt River

Philip Cohen and R. L. Hanson report that the annual flow of the Humboldt River in a reach near Winnemucca, Nev., has been decreasing despite discharge of ground water to the river during most of the year. The losses are attributed largely to evapotranspiration during the spring and early summer. Theoretical mathematical solutions based upon the nonequilibrium formula indicate that increased ground-water withdrawal near the river probably will decrease the flow of the river. The reduction in flow, however, may be considerably less than the gross pumpage, partly because of decreased evapotranspiration losses due to lowering of ground-water levels.

## CALIFORNIA

Because of the diverse terrain and wide climatic differences in California, the water problems in the State are manifold. The water investigations of the Geological Survey include studies of the occurrence, availability, and quality of the surface and ground water and studies of the sediment discharge of streams. These investigations are directed mainly toward delineation of problems of development and toward determination of the causes and solutions of these problems. Basic data are collected on a continuing basis through a Statewide hydrologic network. Some significant findings are summarized below.

### Interbasin movement of ground water in Modoc Lava Plateau

Results of recent studies by R. H. Dale in the Fall River drainage area in the Modoc Lava Plateau indicate subsurface flow from the Tule Lake topographic basin to the Fall River topographic basin. The Fall River basin includes about 600 square miles, but data on streamflow, ground-water levels, and precipitation, plus regional geologic information, indicate that the drainage area tributary to the Fall River is much greater than 600 square miles. Subsurface inflow from the Tule Lake basin presumably moves through highly permeable Recent basalts of the Modoc Lava Plateau. Water-level gradients suggest that ground water is moving southward from Tule Lake, 50 miles away, to discharge at large springs at the head of Fall River.

[35] Sinclair, W. C., 1963, Ground-water appraisal of Duck Lake Valley, Washoe County, Nevada, with a section on the soils of Duck Lake Valley, by Richard L. Malchow: Nevada Dept. Conservation and Nat. Resources Recon. Rept. 15. [In press.]

The area tributary to the Fall River thus includes most of the Tule Lake basin and appears to include about 3,000 square miles.

### Hydrologic inventory of Santa Barbara area

Sustained annual ground-water withdrawals of up to 9,200 acre-feet appear practical in the Carpinteria and Goleta basins in Santa Barbara County. R. E. Evenson, H. D. Wilson, Jr., and K. S. Muir (2–62), through reappraisal of the hydrologic inventory for the 1941–58 period, found significant changes in ground-water storage following increased pumpage. Full use of the ground-water reservoir permits capture and storage of excess runoff, normally wasted to the sea, to supplement the 5,400 acre-feet of annual recharge from infiltration of rainfall and seepage from streams.

### Sediment discharge into San Francisco Bay

In a study of the quantity of sediment transported to the San Francisco Bay system by tributary streams, G. H. Porterfield, N. L. Hawley, and C. A. Dunnam found the average daily sediment discharge during 1957–59 to be about 17,000 tons or 24,000 cubic yards. Central Valley streams transported 82 percent of this sediment into the Sacramento–San Joaquin delta while streams flowing directly into the bay transported 18 percent. Future sediment discharge to the delta and the bay, based on 1959 conditions, is estimated at approximately 8 million cubic yards annually.

## HAWAII

Water-resources investigations in Hawaii include studies of the quantity and quality of the surface and underground waters and are directed toward two main problems: (1) obtaining water most efficiently from the volcanic terrain of the islands, and (2) avoiding sea-water intrusion in coastal areas of greatest development. Some significant findings shown by studies completed or in progress in specific areas are summarized below.

### Ground-water levels stabilized in Honolulu area

Changes in land use in southern Oahu have resulted in an increase in ground-water pumpage and a reduction in the amount of recharge to the basal ground-water body by deep infiltration from irrigated fields. F. N. Visher and J. F. Mink (1–62) found that, between February 1959 and November 1960, water levels in the area declined nearly 3 feet, and the natural discharge at springs in the Pearl Harbor area was reduced by about 20 mgd. Since 1960, little change in water levels and spring flow has taken place, and recharge seems to be in approximate balance with discharge.

### Ground water in the Waianae district, Oahu

In the Waianae district of Oahu, C. P. Zones (1–63) found that test drilling near the shore in 1962 confirmed previous estimates that relatively little ground water discharges into the ocean from the valleys. This is indicated by the chloride content of several thousand parts per million in most of the test wells drilled at the mouth of the valleys, low piezometric gradient, and transmissibilities of 20,000 to 60,000 gallons per day per foot. The discharge into the ocean is estimated as not more than a fourth of the total natural discharge of the valleys, the remainder being lost by evapotranspiration.

Underflow to the ocean from volcanic ridges that extend to the coast is problematic. Several test holes drilled in the veneer of sedimentary rocks overlying the seaward end of the ridges and one that penetrated into the underlying volcanic rocks yielded water of high salinity, which suggests that discharge to the ocean from the ridges is small. A reversal of the chloride gradient was noted at many of the drilling sites. Water just below the water table is brackish but is underlain by water of better quality. The more saline water at the top appears to occur in pockets, possibly as a result of concentration of the dissolved solids by evaporation.

### Quality of ground water deteriorating in northern Oahu

Studies by K. J. Takasaki show that the annual ground-water pumpage for sugarcane irrigation in the Kahuku area in northern Oahu increased from about 6,000 million gallons in 1938 to 9,000 million gallons in 1940, to 12,000 million gallons in 1945, and has averaged about 11,000 million gallons since 1945. From 1945 to 1958 the chloride content of the water in the heavily pumped wells increased substantially, but since 1958 the change has been less marked. Static water levels declined 2 feet between 1938 and 1948 and in 1958 were 3 feet lower than in 1938. In January 1963 the levels were about the same as in 1958. The increase in the chloride content of the water in the heavily pumped irrigation wells probably results from increased pumpage. However, a widespread increase in the chloride content of the ground water underlying the entire area has been noted and is attributed to the return of irrigation water to the ground-water body. The chloride content of the water used for irrigation in a 6-square-mile area ranges from about 400 to 1,600 ppm.

### Surplus ground water in the Mokuleia–Waialua area, Oahu

Test holes in the Mokuleia-Waialua area of Oahu show that shallow ground water in the coastal-plain sediments has a chloride content ranging from 85 to about 9,000 ppm, and that most of the water in the sediments contains less than 500 ppm of chloride. The water occurs under both artesian and water-table conditions, and heads range from 1 foot to 35 feet above sea level. Preliminary studies by J. C. Rosenau, E. R. Lubke, and S. S. Chinn suggest that a considerable quantity of ground water may discharge to the sea through the coastal-plain sediments.

Rainfall measured during 1962 at 18 gages on the summit and northern slope of the Waianae Range indicates that rainfall in parts of the area may be appreciably greater than shown by published estimates.

#### Depletion of ground water in dike complexes, Koolau Range

Through the use of a recession equation George T. Hirashima has determined that the water-development tunnels in the Koolau Range of Oahu have depleted the natural storage in the dike complex by about 30 billion gallons. If this water were restored, the initial discharge from the Koolau tunnels would be approximately 110 mgd. The present discharge from these tunnels is about 40 mgd. The records show a significantly different rate of depletion for tunnels north and south of Waiahok, owing to differences in the number and thickness of the dikes in the two areas.

#### Depletion of ground-water storage by Molokai irrigation tunnel

Construction of the Molokai irrigation tunnel on the island of Molokai, for eventual conveyance of surface waters from the Waikolu Valley to the Hoolehau basin, was accompanied by depletion of approximately 1,500 acre-feet (500 million gallons) of ground water from compartments between the intrusive dikes penetrated. G. T. Hirashima (1–63) found that this depletion occurred in a 2,200-foot length of the tunnel, 80 percent of it in a 1,700-foot section. During 1962, ground-water inflow to the tunnel averaged about 2 mgd and was quite uniform.

#### Dry-weather flow of streams of Hilo-Hamakua coast

Contrary to expectations the total water production during drought periods from the normally wet area on the slopes of Mauna Kea along the Hilo-Hamakua coast, Hawaii, appears to be surprisingly small, according to Dan A. Davis and George Yamanaga (1–63). Dry-weather flow is limited also in the streams on Kohala Mountain. Storage, either surface or underground, will be required to meet water needs of the North Hawaii area.

## MANAGEMENT OF NATURAL RESOURCES ON THE PUBLIC LAND

An expanding economy for the future is dependent upon wise management of the resources of the Nation. The public lands contain a significant portion of these resources, and responsibility for management of the land and use of the resources is exercised by several agencies of the U.S. Government. The U.S. Geological survey, through its Conservation Division, classifies these lands for such resources as leasable minerals and sites for waterpower projects, and supervises the prospecting, development, and recovery of certain minerals from wells and mines under lease, permit, or license on Federal and Indian lands.

The classification functions of the Conservation Division are performed by the Branch of Mineral Classification and the Branch of Waterpower Classification. The supervisory functions are performed by the Branch of Mining Operations and the Branch of Oil and Gas Operations. The Conservation Division also supervises the administration of the Connolly Act of February 22, 1935.

Field offices of the Division are listed on page A252. Geologic and hydrologic work in progress by geologists and engineers of the Conservation Division is given in the list of investigations starting on page A259, under the categories of geologic mapping, glaciology, waterpower classification, and various commodities such as coal and petroleum and natural gas. Scientific and economic results of these investigations are published as books and maps in the regular series of Geological Survey publications.

### CLASSIFICATION OF MINERAL LANDS

The principal leasable minerals are oil, gas, oil shale, coal, phosphate, sodium, and potash. Since 1906, public lands believed to contain leasable minerals have been withdrawn from entry by the Secretary of the Interior, on the advice of the Geological Survey, pending their classification as mineral or nonmineral lands. At present about 45 million acres of land are so withdrawn.

To classify the land according to uniform standards, the geology is mapped in detail, generally at a scale of 1:24,000. Existing geologic maps of adequate scale and quality are used if they are available. Mapping for mineral land classification, however, differs in some details from general geologic mapping in that more measurements of stratigraphic sections per quadrangle are required to show thicknesses of coal or other leasable minerals, and more frequent sampling is necessary to determine the quality. Subsurface evaluations utilizing drill-hole cuttings, cores, and electric or radioactivity logs also provide data for classification. Samples obtained from surface and subsurface operations are submitted for laboratory analyses. When the extent, thickness, and grade of the minerals are established, the land is classified as to its mineral resources. The geologic maps produced are published in the standard map series of the Geological Survey.

## WATERPOWER CLASSIFICATION

Classification of public lands to conserve and utilize water resources was begun in 1888, to preserve reservoir sites for irrigation. It has been continued chiefly for hydroelectric development. Present activity includes stream-basin investigations, a review of land classifications and reserves, and the measurement of selected glaciers.

The program of stream-basin investigations is a systematic search for basins and subbasins where water projects can be developed in the future to serve the needs of a growing population. Sites that meet the criteria for classification are set aside by the Secretary of the Interior on the recommendation of the Geological Survey, through procedures established by Congress and the Department of the Interior. Land set aside by these procedures may not be disposed of for lesser purposes, and if the land is disposed of, it may be reacquired by the Government for purposes of waterpower development without cost.

A program of review of land classification and reserves was begun in 1956 to reassess all classifications, many of which had been made before 1920 under Congressional and departmental urging for immediate protection of sites for waterpower development. Because of urgency the classifications were based on inadequate mapping and hydrologic data. Under the present program all reserves are being reevaluated and classified by rigorous standards. Lands that do not qualify as waterpower sites are removed from the reserves, and are open to disposition under public-land laws. Progress through fiscal 1963 on this program indicates that as much as 40 percent of lands now reserved for waterpower may eventually be eliminated from the reserves.

River basins and lakes are mapped mostly at a scale of 1:24,000. Contours of river and lake bottoms are compiled by precise sounding surveys. The results of investigations are published as special maps and sheets.

A special project to gather information on the rates of ablation and the recession or advance of selected glaciers was started in 1941 on Nisqually Glacier in Mount Ranier National Park, Wash., and in 1944 on Grinnell and Sperry Glaciers in Glacier National Park, Mont. Annual measurements are made at monumented cross sections, and the glaciers are mapped completely at 5-year intervals. The National Park Service cooperates in this program. In 1961, at the request of and in cooperation with the Bureau of Reclamation, measurements were begun on Barrier Glacier, Mount Spurr, Alaska, to determine what effect the growth or shrinkage of the glacier has on fluctuations in the level of Lake Chakachamna.

## SUPERVISION OF PROSPECTING, DEVELOPMENT, AND RECOVERY OF MINERALS

Supervision of operations under mineral leases entails the following: investigating lands and deposits under application for mineral leases, oil and gas leases, and prospecting permits; recommending lease terms and unit areas; enforcing operating regulations and measures to assure the safety and welfare of workmen; maintaining production records; and determining and collecting royalties and rentals. The mineral supervisory branches of the Conservation Division also act as advisors to the Secretary of the Interior, to other bureaus of the Department, and to other Government agencies concerned with the administration of the Mineral Leasing Acts as amended.

Royalties from public lands are distributed 52½ percent to the Reclamation fund, 37½ percent to the States in which the minerals or fuels are produced (except for Alaska, which receives 90 percent), and 10 percent to the Federal Treasury. Royalties from other land categories are distributed in many different ways as provided by law, but the largest share of these royalties is returned directly to the Federal Treasury.

### Branch of Mining Operations

The Branch of Mining Operations supervises operations concerned with discovery, development, and production of coal, oil shale, phosphate, potassium, solid and semisolid bitumin, and sodium from public land; and of sulfur from public land in Louisiana and New Mexico. The branch also supervises the production of silica sand on certain lands in Nevada; mercury on certain Spanish land grants; all minerals except oil and gas on restricted, allotted, and tribal Indian lands; and all minerals recoverable in commercial quantities, except oil and gas, on acquired lands.

The following table shows production of minerals and royalties received from leased Federal lands under supervision of the Branch of Mining Operations for the fiscal year ending June 30, 1963.

| Land category | Production (tons) | Value (dollars) | Royalty (dollars) |
|---|---|---|---|
| Public | 20, 622, 000 | 141, 083, 000 | 5, 842, 000 |
| Acquired | 92, 000 | 867, 000 | 34, 000 |
| Indian | 5, 737, 000 | 20, 408, 000 | 2, 003, 000 |
| Total | 26, 451, 000 | 162, 358, 000 | 7, 879, 000 |

## Branch of Oil and Gas Operations

The Branch of Oil and Gas Operations supervises the discovery, development, and production of crude oil and natural gas and associated products from leased public, acquired, Indian, outer continental shelf, and Naval Petroleum Reserve lands. About 12 percent of United States oil production in 1962 came from leases on Federal lands.

The following table shows the production of crude oil, the value of petroleum products, and the royalties received from supervised leases on the various categories of Federal and Indian lands during fiscal 1963.

| Land category | Production (barrels) | Value (dollars) | Royalty (dollars) |
|---|---|---|---|
| Public | 173, 040, 000 | 544, 164, 000 | 67, 788, 000 |
| Outer continental shelf | 93, 929. 000 | 388, 182, 000 | 68, 959, 000 |
| Acquired | 6, 093, 000 | 22, 261, 000 | 2, 807, 000 |
| Military and miscellaneous | 2, 814, 000 | 23, 213, 000 | 4, 872, 000 |
| Naval Petroleum Reserve No. 2 | 3, 851, 000 | 14, 500, 000 | 1, 964, 000 |
| Indian | 41, 949, 000 | 125, 655, 000 | 17, 225, 000 |
| Total | 321, 676, 000 | 1, 117, 975, 000 | 163, 615, 000 |

# GEOLOGY AND HYDROLOGY APPLIED TO ENGINEERING AND PUBLIC HEALTH

Some of the work of the U.S. Geological Survey is designed to provide geologic and hydrologic information that is directly applicable to problems of engineering and of public health and safety. Major activities include investigations for the Atomic Energy Commission concerning engineering geology and hydrology of test sites for nuclear explosions, and disposal of radioactive wastes; investigations of water contamination; studies of the natural distribution of elements as related to public health; and investigations of geology and hydrology related to engineering problems in construction, mining, water management, and flood control.

## INVESTIGATIONS RELATED TO NUCLEAR ENERGY

Underground testing of nuclear devices and the generation of power by nuclear reactors release radioactive products to the geologic and hydrologic environments. To safeguard the public, the distribution, movement, and concentration of these products must be determined and the potential danger evaluated. Since 1956 the U.S. Geological Survey has provided geologic and hydrologic data on the environment of reactor and underground test sites at the Nevada Test Site, and at sites for program PLOWSHARE and other experiments in other parts of the United States, and has evaluated these data for the Atomic Energy Commission. Some results of the Geological Survey's early experiments with conventional explosives, precursors of the first underground nuclear tests, were published by Cattermole and Hansen (1–62).

During 1962, intensive geologic and hydrologic studies were carried on because of continued underground testing of nuclear devices, and because of increased interest in the peaceful application of nuclear explosions and the application of nuclear energy to space programs.

### *NEVADA TEST SITE STUDIES*

Geologic, geophysical, and hydrologic investigations during 1962 ranged from reconnaissance of large areas to highly specialized study of specific test sites. Major broad problems included: (1) the structure and geologic evolution of the Timber Mountain caldera; (2) stratigraphy and correlation of many previously unrecognized sequences of volcanic rocks, particularly rhyolites and old welded tuffs in the western part of the Nevada Test Site; (3) evaluation of the geology of Pahute Mesa in the northwestern part of the Nevada Test Site; (4) synthesis of past Geological Survey studies of the Yucca Flat area; (5) geology and hydrology of a potential new townsite southeast of the Nevada Test Site; (6) mineralogic and petrographic study of the Indian Trail tuffs; (7) interpretation of gravity and aeromagnetic surveys; and (8) interpretation of the results of deep exploratory drill holes.

Major specific site problems included: (1) study and analysis of particular test media such as basalts similar to those used previously on Buckboard Mesa in the western part of the Nevada Test Site for cratering experiments, and carbonate rocks, particularly pure limestone; (2) pre- and postshot studies of the geologic environment of the MARSHMALLOW and HARDHAT events; (3) further analysis of the structure of subsidence sinks; (4) study of the physical and chemical nature of the alluvium in Yucca Flat by surface and subsurface mapping and sampling, and by analysis of samples in the laboratory; (5) analysis of fracturing in alluvium of Yucca Flat; (6) prediction of the character of rocks at depth at the PLUTO underground air-storage site; (7) additional study of the geologic effects of the LOGAN and BLANCA events; and (8) analysis of distribution and thickness of alluvium and tuff in Yucca Flat by the use of gravimetric surveys and exploratory drilling.

#### History of the Timber Mountain caldera

Of particular geologic significance in the understanding of volcanic structure in the Southwest is a preliminary interpretation by F. M. Byers, W. J. Carr, P. P. Orkild, and R. L. Christiansen (1–63) of the structure of the Timber Mountain caldera, in the western part of the Nevada Test Site. Timber Mountain, in the apparent center of the caldera, is a dome of welded tuffs more than 2,500 feet thick and older than the tuffs of the widespread Indian Trail and Piapi Canyon Formations. The latest major collapse of the caldera postdates the deposition of the Indian Trail Formation and all but the uppermost part of the Piapi Canyon Formation, which was deposited both inside and outside the caldera after this major collapse. The distribution of the cooling units of the Piapi Canyon Formation indicates that the source area for the lower units was in what is now the southern and eastern moat of the Timber Mountain caldera. The upper units may have had a source in the northern or northeastern moat area. P. W. Lipman and R. L. Christiansen mapped basin-and-range-type faults that have an increased displacement toward the Timber Mountain caldera and are cut by ring faults of the caldera. Lipman suggests that these fault relations indicate early doming preceding caldera collapse in late Piapi Canyon time.

#### New volcanic sequences recognized

Detailed geologic mapping in the western part of the Nevada Test Site and reconnaissance mapping of the surrounding area has delineated several new sequences of volcanic rocks that are in part equivalent to, and in part older than, the Indian Trail and Piapi Canyon Formations of the eastern and central parts of the Test Site. Many of the rhyolites that are common throughout the western part of the Nevada Test Site correlate with various parts of the Indian Trail Formation. These lithologically similar rhyolites are discontinuous and are sporadically distributed, but progress has been made by K. A. Sargent in correlating them by heavy minerals, particularly zircon. Study of the flow banding in the rhyolite of Comb Ridge by R. L. Christiansen has aided in determining flow direction and understanding flow configuration. Similar studies of eddy zones caused by inclusions has enabled David Cummings to demonstrate flow direction in rhyolites in southern Pahute Mesa.

#### Geology and hydrology of Pahute Mesa studied

Preliminary to an exploration program, the geologic and hydrologic environment of Pahute Mesa was studied by rapid reconnaissance mapping north of the Nevada Test Site, and by projecting the Tertiary volcanic stratigraphic units over many square miles and to considerable depth. Gravimetric surveys by D. L. Healey, C. H. Miller, and others indicate as much as 10,000 feet of volcanic rocks beneath central Pahute Mesa—the thickest section of volcanic rocks found to date at the Test Site.

#### Structural interpretation of Yucca Flat

A minimum of four extensive thrust plates have been tentatively outlined in the surface and subsurface Paleozoic rocks of Yucca Flat. Gravimetric surveys have aided in these fault interpretations. F. A. McKeown has suggested high-angle fault sets represented by vectors in different parts of Yucca Flat as one form of geologic data that may aid seismologic and hydrologic interpretations. A broad northeast-trending mineral belt extending from the Hornsilver area, southwest of Yucca Flat, to Groom Valley, north and east of Yucca Flat, is inferred from study of the mineral deposits.

#### Thickness of alluvium and nonwelded tuff

Drilling in Yucca Flat and geologic mapping in the bordering mountain ranges, combined with gravimetric surveys, have provided data on the distribution and thickness of alluvium and nonwelded tuff, which are the two desirable test media in the area. The combined thickness of the two rock media ranges from 0 to more than 5,000 feet. The lenticular mass, however, contains a buried north-south ridge in the western part of the flat. Areas of welded tuff restrict underground test-site development in Yucca Flat. Two intercalated welded tuff units of the Piapi Canyon Formation are the Rainier Mesa Member, which extends throughout most of the valley, and the Topopah Spring Member, which is widespread in the southern third. Maximum thicknesses of these members under Yucca Flat may be as much as 600 feet, and their combined thickness may be as much as 1,100 feet in the southern part of the valley. Thus it may become necessary to conserve desirable test areas in much the same way that we now conserve other more commonly considered natural resources.

#### Common source for members of Piapi Canyon Formation

Initial mineralogic and petrographic studies by R. D. Krushensky of stratigraphically closely controlled samples of tuffs of the Piapi Canyon Formation in the northern part of the test site show a marked increase in magnesium content of pyroxenes and amphiboles in successively younger rocks. The general trend is thought to indicate successive tapping of the more basic parts of a magma reservoir that was the common source for many members of the Piapi Canyon in this part of the test site.

#### Single source proposed for ash-flow tuffs of Timber Mountain dome

Detailed petrographic and chemical study by W. D. Quinlivan of the 2,500-foot minimum of ash-flow tuffs in the Timber Mountain dome indicates that this sequence records at least one upward change in composition from early silicic to later more intermediate flows. The formation of these flows into a composite sheet suggests that the acid and intermediate differentiates were extruded without appreciable intervening time. Multiple vents from different parts of a single magmatic source are suggested.

#### Magnetic susceptibility used in correlating basalts

Correlation of magnetic susceptibility with grain densities of olivine basalts in the Skull Mountain–Jackass

Flats area of the southwestern part of the Nevada Test Site has been used successfully by K. A. Sargent to distinguish two structurally critical basaltic units that are otherwise lithologically similar.

### Elastic properties of volcanic rocks

In studies of dacite at the PLUTO air-storage site, J. R. Ege concluded that difficultly determined elastic properties of these rocks could be extrapolated on the basis of easily determined properties such as porosity, grain density, bulk density, and magnetic susceptibility. Similar studies of the basalt at Buckboard Mesa led R. E. Davis to conclude that the same approach could be used for basalts.

### Plants useful in detecting nuclear explosions

Preliminary botanical studies by H. L. Cannon at several areas in the Nevada Test Site suggest that plants may be used to detect nuclear explosions. Changes in plant species, floral assemblages, plant morphology, and plant chemistry occur on irradiated ground as much as several hundred feet away from the BLANCA shot in 1958. The year of the shot is clearly recorded in the tree ring pattern of affected oak trees.

### Hydrothermal alteration used to delineate intrusive body

Hydrothermal alteration in the Calico Hills of north Jackass Flats has been studied by E. J. McKay to delineate the buried intrusive body underlying the Calico Hills structural dome. This provides control for interpretation of an associated aeromagnetic anomaly.

### Geophysical studies

Remanent magnetism of specific members of the Piapi Canyon formation, and the general thick section of volcanic rocks of Rainier Mesa are believed to be responsible for deep negative magnetic anomalies in the Rainier Mesa area and to the northwest around Pahute Mesa. The delineation of the buried boundary of the Timber Mountain caldera may be possible by analysis of the anomalies, if they can be properly neutralized.

A detailed gravimetric survey by D. L. Healey and C. H. Miller (Art. 18) has been used to determine a possible subsurface configuration of the Gold Meadows granitic intrusive beneath Rainier Mesa in the north-central part of the Nevada Test Site.

Two nomographs have been developed by J. H. Scott (Art. 20) to facilitate the interpretation of large amounts of resistivity data obtained at the Test Site. These nomographs are general in nature and can readily be applied to resistivity-data interpretation problems elsewhere.

### Studies of explosion effects

From study of the effects of the LOGAN, BLANCA, and RANIER events, F. A. McKeown has suggested a method of determining relative stress-wave attenuation as a function of the directions and frequencies of the natural fractures toward any given point in the vicinity of the shot. The method may be useful in predicting damage to tunnels or installations as the result of rock spalled by reflected stress waves at free surfaces.

The structure of collapsed sinks in Yucca Flat has been subdivided into five zones by F. N. Houser and W. P. Williams, an important first step in the study of the mechanism of collapse of contained underground tests.

Studies by F. N. Houser and W. L. Emerick of results of the HARDHAT experiment in the Climax stock suggest that fractures produced by the explosion bear a shear-and-tension relation to the direction of stress-wave propagation and that the natural fractures deflect the stress wave. The information was used to modify a proposed design for another experiment in the same stock.

### Interbasin movement of ground water confirmed by drilling

Deep test drilling to the Paleozoic carbonate rocks confirmed an earlier hypothesis (Winograd, 1–62) that the three intermontane basins at the Nevada Test Site are hydraulically connected and are tributary to discharge areas in the Amargosa Desert to the southwest. Ground water moves through highly fractured Paleozoic carbonate rocks which flank and underlie the basins. A reconnaissance study by Eakin, Schoff, and Cohen of a 12,000-square-mile area in south-central Nevada suggests further that ground-water basins east, northeast, north, and northwest of the Test Site may also be tributary to the Amargosa Desert (p. A48).

Data from the test holes showed also that the Paleozoic clastic rocks, where they form thick relatively continuous bands, apparently are barriers to interbasin movement of ground water, and that the dominant direction of ground-water flow may be inferred from the outcrop pattern of these strata. Drill-stem tests and core examination indicate that the effective porosity of the Paleozoic carbonate aquifers and some of the brittle clastic rocks is of the fracture type, that fractures or fault planes are open to depths of at least 5,000 feet, and that great thicknesses of these strata form a single hydraulic unit regardless of stratification, presumably because of the intense fracturing. Hydraulic gradients in the carbonate aquifers are as low as 0.5 foot per mile. These gentle gradients necessitated correction of water-

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level measurements for hole deviation, water temperature, and wear of measuring devices to obtain comparable heads for use in the preparation of potentiometric maps of the area. Special recording gages were required for precise records of water-level fluctuations because of the great depths to water.

Study of the chemistry of ground water of the Cenozoic and Paleozoic aquifers by S. L. Schoff and J. E. Moore has demonstrated, independently of hydraulic data, that ground water at the Nevada Test Site is moving probably toward the Amargosa Desert. Their study shows further that interbasin flow through the Cenozoic strata is unlikely.

The maximum velocity of ground-water movement within the Paleozoic carbonate aquifers immediately south of the Test Site, estimated from the hydraulic gradient and the measured spring discharge within the Amargosa Desert, is less than 5 feet per day; the velocity beneath the Test Site is probably a fraction of this rate. The average rate of downward movement of water through the thick and widespread Tertiary zeolitized tuffs, which separate the Cenozoic aquifers from the Paleozoic aquifers in Yucca Flat, is probably a fraction of a foot per day.

#### New cesium-137 batch method for cation-exchange determinations

In studies of ion adsorption at the Nevada Test Site, Beetem, Janzer, and Wahlberg (1–62) developed a batch method for determining cation-exchange capacity using cesium-137. The new cesium-137 method is more precise than the ammonia and manganese batch methods. More recent studies by Beetem (1–63), using the mass-action equation, showed good correlation between distribution coefficients, equilibrium constants, and cation-exchange capacity for data on mixed clay systems.

#### Effect of explosion on infiltration rates

The Geological Survey participated in project SEDAN, a cratering experiment in July 1962, to obtain additional information on the effectiveness of higher yield nuclear devices for excavation and on the resultant fallout. Measurements made by W. C. Rasmussen of the infiltration rates of the surficial materials near the SEDAN site, before and after the shot, indicate that the postshot surficial material had an average infiltration rate 30 percent less than that of the preshot surficial material.

## STUDIES AT OTHER SITES

In addition to investigations for defining the geology and selecting sites for underground nuclear experiments and reactor development at the Nevada Test Site, the Geological Survey is involved also in projects at many other locations that concern (1) rock characteristics at established and potential missile sites; (2) peaceful uses of atomic energy (the PLOWSHARE program), including projects GNOME, CHARIOT, and SCHOONER, and (3) detection of nuclear explosions (the VELA program), including project DRIBBLE.

#### Project GNOME

Project GNOME involved the detonation of a 5-kt nuclear device in salt of the Permian Salado Formation near Carlsbad, N. Mex. The Survey provided much of the basic geologic, geophysical, and hydrologic data needed to evaluate the geologic environment and to appraise observed postshot geologic effects.

Detailed postshot geologic mapping by L. M. Gard (1–63) of the reentry drift to the cavity created by the explosion showed that explosion-induced effects included displacement of the rock along many small thrust faults. In one area, intrusive breccia veins that were formed by the blast contained galena and laurionite, a lead chloride identified by Theodore Botinelly. The minerals were formed by the reaction of lead, surrounding the nuclear device, with water and the constituents of the salt beds.

Data on distribution coefficients for samples from the GNOME shaft were used by Janzer and others (1–62) to predict the probable velocity of movement of radioactive contaminants dissolved in ground water relative to the movement of the ground water. Adsorption of cationic radionuclides (carrier-free cesium, strontium, and mixed fission products) increased with time. Distribution coefficients obtained after 120 days of contact were comparable to those obtained after 30 days. In general, the degree of adsorption of radionuclide by the earth-material samples decreased with increased salt concentrations.

Water samples collected from observation wells in the vicinity of the GNOME site several months after the GNOME shot show no change in radioactivity from that in water samples before the shot. Similarly, a pumping test made in March 1963 of the principal aquifer, the Culebra Dolomite Member of the Rustler Formation, indicates no discernable change in the coefficient of permeability of the aquifer near the site as a consequence of the GNOME shot.

#### Project DRIBBLE

Project DRIBBLE is an experiment consisting of a series of nuclear explosions in manmade cavities in salt at Tatum dome, Lamar County, Miss., to test the effect of decoupling on the detectability of underground nuclear explosions. Recent work includes a mineralogic study of the salt-dome complex and its overlying beds by J. Schlocker, and a study of the stratigraphic sequence in the region surrounding the Tatum dome by D. H. Eargle.

Hydrologic studies show that water in sand and limestone aquifers overlying and surrounding the dome is moving at less than 10 feet per year. Laboratory studies by W. A. Beetem and V. J. Janzer on the distribution coefficients for various radionuclides, considering the sands and silty clays around the dome in relation to differing quality of water, show that the movement of strontium radioisotopes would be retarded by a factor ranging from 4 to 309, and cesium isotopes by a factor ranging from 27 to 761, with respect to the velocity of ground water.

## DISPOSAL OF RADIOACTIVE WASTES

The U.S. Geological Survey has continued in 1963 its investigation of the geologic, hydrologic, and geochemical aspects of the disposal of radioactive wastes. Topical and areal studies are in progress at six installations of the U.S. Atomic Energy Commission (AEC), in Geological Survey offices and laboratories, and at several field locations throughout the United States. In addition, appraisals of several sites proposed for nuclear installations were made to determine the capacity of streams and the ground to accept radioactive wastes.

### Movement of radionuclides in streams

The fate of radionuclides introduced into the Clinch and Tennessee Rivers at Oak Ridge National Laboratory, Tenn., and into the Columbia River at the Hanford Atomic Products Operation, Wash., is being studied in two major projects.

Work at Oak Ridge is part of comprehensive studies by several Federal and State agencies to determine the physical, chemical, and biological factors controlling the capacity of the stream system to accept, without hazard to man, liquid effluents having low levels of radioactivity. P. H. Carrigan, B. J. Frederick, E. P. Mathews, R. J. Pickering, and others have contributed to the findings of the Clinch River steering committee.[36]

They found from flow-duration and frequency studies that in any year the probability is 50 percent that the dilution for a 30-day period will be less than 130 times; the probability is 10 percent that dilution will be less than 78 times. Although bottom sediments play an important role in the deposition of some radioactive materials, most of the radioactivity passes downriver through the Tennessee River system. Problems in sampling led to the use and modification of several interesting methods. Carrigan and Pickering found that certain observations could be made only by a "first-hand look" and qualified themselves as SCUBA divers so that they could inspect the bottom sediments in place. In addition, Pickering [37] took more than 100 undisturbed cores with the Swedish foil sampler, a piston-type sediment sampler which utilizes thin metal axial strips to minimize friction between the sediment core and the sample tube as the core is taken. Radioactivity measurements of the cores have shown substantial variations in gross gamma radioactivity with depth in the sediment.

Radionuclides in the Columbia River below Hanford, Wash., are transported in solution, adsorbed on sediments in suspension and on the bottom, and in association with plant and animal life. Preliminary results of a study of radionuclides transported in solution and adsorbed on sediment indicate that a relatively large part of the radioactivity is transported with the sediments and that the concentration is very much higher on the sediments than in the water. Because of the size of the stream and the complexity of the hydraulic, chemical, and sedimentological variables it will be difficult to make an accurate dynamic inventory of the radionuclides being transported in the several phases of the river system. One particularly difficult problem has been to compute stream discharge in the lower reaches of the Columbia and Willamette Rivers, which are affected by tides. Methods developed by R. A. Balzer and John Shen involve the use of two gaging stations, one at each end of a reach. The stage data are used in a computer program to solve the flow equations. For the water and sediment phases it has been necessary to develop an optimum sampling frequency, both with respect to time and to spacing in a given cross section, by means of statistical analysis.

In a study of distribution of radioelements in ground and surface water of the Shirley basin south of Casper, Wyo., R. C. Scott found that installation of a well field and pumpage of ground water to lower the water table around major uranium ore bodies has modified the chemical character of nearby stream water. However, within 3 miles of the well field, the radium concentration drops to about normal background levels; probably the radium is adsorbed on sediments in the stream beds. Uranium, on the other hand, remains above background concentrations by at least a factor of 10 throughout the basin along a reach of about 30 miles of the Little Medicine Bow River. Radon concentration in water from the Wind River Formation (the ore horizon) ranges from 3,600 to 200,000 picocuries per liter ($10^{-12}$

[36] Morton, R. J., ed., 1962a, Status report No. 2 on Clinch River study: Oak Ridge Natl. Lab-3202, Nov. 21, 1962.
Morton, R. J., ed., 1962b, Status report No. 3 on Clinch River study: Oak Ridge Natl. Lab–3370. [In press]

[37] Pickering, R. J., 1963, Use of the Swedish foil sampler for taking undisturbed cores of river bottom sediments: Proc. Federal Interagency Sedimentation Conf., Jan. 28 to Feb. 1, 1963, Jackson, Miss., U.S. Dept. Agriculture Misc. Pub. [In press]

c/1), but springs in the overlying nonuraniferous White River Formation contain only 750 to 2,200 picocuries radon per liter.

### Movement of radionuclides underground

Movement of radioactive wastes discharged into seepage pits and into a disposal well has been studied intensively at the National Reactor Testing Station (NRTS), Idaho. Rates and directions of groundwater travel away from an injection well have been measured using tritium and other radionuclides present in low-activity liquid wastes discharged into the well as tracers. This work was reported by P. H. Jones and B. L. Schmalz,[38] who found that "first-arrival" travel velocities ranged from 24 to 141 feet per day out to 3,500 feet downgradient from the disposal well. As a result of spatial variations in transmissibility and pressure head, the waste plume is dispersed through an angle of about 90°.

A new concept for the storage of highly radioactive wastes that result from chemical reprocessing of reactor fuels is being studied at the AEC Savannah River Plant near Aiken, S.C. I. W. Marine and G. E. Siple have participated in an investigation of the feasibility of storing these wastes in a mined cavity in metamorphic rocks more than 1,500 feet below ground rather than in buried steel tanks near the land surface, as is current practice. The most important safety aspect of the feasibility appraisal involves the likelihood of transport of long-lived radioactive materials such as strontium-90 and cesium-137 with naturally occurring ground water through fractures in the rock. By detailed hydraulic tests on selected depth intervals in 7 drill holes, and by controlled pumping tests in 2 of the holes, the distribution of water-bearing fractured zones in the bedrock has been mapped by Marine. Measurements by Siple and Marine showed that the head of highly mineralized water in the metamorphic rock was about 20 feet higher than that of relatively fresh water in the overlying Cretaceous sands.

At the Los Alamos Scientific Laboratory, N. Mex., the Survey for many years has studied problems of water supply and the effect of disposal of radioactive wastes on water resources. By analysis of data from pumping tests of the water-supply wells and by mapping hydraulic gradients, C. V. Theis and C. S. Conover[39] found that it would take at least 70 years for low-level liquid wastes to traverse the 5 miles from the recharge area to the well field.

[38] Jones, P. H. and Schmalz, B. L., 1963, Distribution of radionuclides in ground water at the National Reactor Testing Station, Idaho, with particular reference to tritium: U.S. Geol. Survey open-file report.

[39] Theis, C. V., and Conover, C. S., 1962, Pumping tests near Los Alamos, New Mexico: U.S. Geol. Survey Water-Supply Paper 1619-I, 24 p.

E. H. Baltz, J. H. Abrahams, Jr., and W. D. Purtyman (2–63) have made a detailed study of the geology and hydrology of Mortandad Canyon near Los Alamos, N. Mex., near the site of a new treatment plant for radioactive wastes. By describing the geology and by measuring the in situ natural-state moisture content of soils and rocks, the streamflow, and variations in hydrostatic head in perched aquifers over a period of 2 years, a sound basis has been laid for evaluating the effects of waste disposal on the drainage basin. They conclude that waste liquids will infiltrate into the upper and middle reaches of the canyon and then move underground through alluvium. Clay in the alluvium will probably remove most of the radionuclides in the waste near the point of infiltration.

In collaboration with personnel of the Los Alamos Scientific Laboratory, C. M. Bunker and W. A. Bradley (2–62) studied conditions in a small tile-drain field constructed at Jackass Flats, Nev., for the seepage disposal of liquid radioactive wastes in alluvium. They made successive gamma-ray logs of small-diameter shallow borings in the tile field before and after the injection of simulated and real waste liquids. Although the success of the method was limited by the small amounts of radioactivity in the waste and in the test solutions, they found that the radioactivity was confined to a zone within a few feet of the seepage tile.

### Disposal of radioactive wastes in sedimentary basins

Deep-well disposal of radioactive wastes has great potential for the future, when facilities producing liquid nuclear wastes will be more widespread than they are today. Before the method can be used at a potential site, it will be necessary to know the subsurface geology of the rocks and the condition of their contained fluids in considerable detail.

Helen Beikman (1–62) has summarized the geology of a potential site, the Powder River Basin of Wyoming and Montana. She suggests that reservoirs suitable for disposal of fluid wastes may be found in the Flathead Sandstone, Tensleep Sandstone, and Sundance Formation of pre-Cretaceous age and in sandstone beds of the Fall River, Lakota, Newcastle, Frontier, Coda, and Mesaverde Formations. Several thick sequences of shale in the Cretaceous section might be suitable for storage by the hydraulic-fracturing disposal technique.

C. A. Sandberg (3–62) summarized the geology of the Williston basin and found that the Winnipeg Formation and the Newcastle Sandstone may be suitable for the injection of fluids. Salt beds are present in which cavities for waste storage might be dissolved, but these are at considerable depth, and shale beds in

Cretaceous deposits may be suitable for hydraulic fracturing.

Rock salt is a dry geologic medium in which calcined or fused solids that have been formed by dehydration of highly radioactive liquid wastes may be stored. Because a knowledge of the distribution of rock-salt deposits is important for planning future waste-disposal activities of this type, W. G. Pierce and E. I. Rich (1–62) have mapped and described salt deposits in 24 States, some deposits of which have a lateral extent of several hundred miles. Large volumes of space are available in cavities that have already been mined out, and new space could be developed at relatively low cost.

#### Geologic and hydrologic evaluation of sites of nuclear-energy facilities

A number of sites for reactor and other nuclear-energy installations have been studied on behalf of the Atomic Energy Commission as well as other governmental agencies. Special emphasis is placed on evaluating potential hazards to water supplies in the event of accidental discharge of radionuclides. Studies cover sites for a research and test reactor proposed by the U.S. Bureau of Standards at Gaithersburg, Md., a power-demonstration reactor near LaCrosse, Wis., future nuclear-rocket launching facilities at Cape Canaveral, Fla., and a chemical plant for reprocessing reactor fuels in western New York State.

In a study of the site for a power facility at Hallam, Nebr., C. F. Keech (1–62) found that the site is underlain by unconsolidated deposits of Pleistocene age more than 400 feet thick, from which copious supplies of ground water are pumped. Radioactively contaminated liquid that might be spilled on the site would probably be retained in one or both of two structures installed for retarding water. If radioactive fluids were to get past these structures, they would flow into Salt Creek and thence into the Platte River. Salt Creek is not used as a source of drinking water, and serves in only a few places as a source for irrigation.

## WATER-CONTAMINATION STUDIES

With increasing growth of population and industry, reuse of water is necessary in most areas of the United States. The complex organic chemistry involved in some of the industrial processes, and the large household use of synthetic detergents increase the problem of treating water for reuse. Additional problems are caused by the necessity of disposing of fluid wastes without harming surface or subsurface sources of water supply. Some U.S. Geographical Survey findings in studies of contamination of water are outlined below.

#### Environmental classification for disposal of fluid wastes

In order to formulate a systematic procedure for evaluating sites for the disposal of fluid wastes, H. E. LeGrand has outlined the environmental factors that must be considered at any site, and their interrelations. The factors are: (1) the depth of water table below the waste source, (2) the sorption in terms of types of earth materials, (3) the permeability in terms of types of earth materials, (4) the approximate average gradient between a waste site and a well, and (5) the distance from point of ground contamination to point of ground-water use.

#### Laboratory studies of behavior of detergents

The behavior of detergents and other contaminants in soil-water environments is being studied by C. H. Wayman, J. B. Robertson, and H. G. Page. The work is concerned with the influence of physicochemical and biochemical properties of detergent solutions on movement through the unsaturated and saturated zones. Some significant findings are:

1. Measurements of the surface tension of anionic, cationic, and nonionic surfactants (such as detergents) with the Cassel-type tensiometer showed that the greatest change in surface tension-concentration gradient takes place in solutions containing up to 25 ppm of surfactant material (Wayman and others, 4–62, fig. 179.1). The surface tension of cationic and nonionic surfactants decreases with increase in pH; the surface tension of anionic surfactants increases with increase in pH. The surface tension of waste-water solutions should be considered when ground-water recharge studies and infiltration characteristics are evaluated. Detergents in waste water would increase drainage rates in coarse sand, but in clayey materials they would tend to decrease capillary flow.

2. The Gibbs' adsorption equation was applied to synthetic-detergent solutions by Wayman (2–63). The surface excess, as calculated from the slope of the surface tension-concentration curve, and Avogadro's number were used to calculate the cross-sectional area of the synthetic detergent alkylbenzenesulfonate (ABS). Such calculations are useful in assessing the peculiar type of absorption at solid-liquid interfaces. The critical micelle concentration of the detergent studied was 1,000 ppm based on surface-tension data.

3. The potential of the natural clay minerals kaolinite (Wayman and others, 3–63), illite (Art. 119) and montmorillonite (Art. 59) to remove ABS from water has been investigated. All the clays had adsorption capacities ranging from 200 to 400 micrograms of ABS per gram of clay at ABS concentrations of as much as 10 ppm. ABS containing 15 carbon atoms in the alkyl

chain is adsorbed to a greater extent than ABS containing 12 carbon atoms. Other variables that produce optimum adsorption of ABS on clays are acid solution (pH 4), salts in solution (NaCl, $CaCl_2$ or $AlCl_3$) up to 1,000 ppm, and in some tests orthophosphate in solution. Clays are relatively inefficient as adsorbents for ABS in comparison with activated charcoal or activated alumina, but are less expensive.

4. Studies of the growth of pure cultures of coliform bacteria at 10° to 35°C in acid to alkaline solutions containing detergent constituents indicate that bacteria survive longest in detergent solutions at low temperatures and at neutral and alkaline pH (Art. 57). Phosphate, carboxymethylcellulose, and other constituents of household detergents contribute to bacterial survival. Low concentrations of ABS have no nutrient value, and high concentrations tend to be toxic to bacteria.

#### Detergents in Long Island ground water

Analyses of water from groups of observations wells screened in glacial outwash, at depths ranging from 12 to 77 feet below land surface at three public-supply well fields in southern Suffolk County, Long Island, N.Y., show concentrations of ABS as high as 1.5 ppm. N. M. Perlmutter and I. H. Kantrowitz, continuing studies by Pluhowski and Kantrowitz,[40] report that the source of the ABS is seepage from hundreds of domestic cesspools upgradient from the well fields. The pattern of fluctuations in concentrations of ABS in 1961–62 was not always the same at all depths. The largest fluctuations occurred in the 15- to 44-foot depth range. Variations in concentration probably are affected mostly by (1) the amount of ABS discharged upgradient, (2) variations in precipitation, (3) rate and duration of pumping at the well fields, and (4) geochemical influences on the contaminated water as it moves through the ground.

#### Nitrate in Long Island ground water

Nitrate concentrations ($NO_3$) ranging from about 20 to 69 ppm were noted by John Isbister in the shallow ground water of east-central Nassau County, Long Island, N.Y. The nitrates probably originate in part from chemical fertilizers, which were used extensively in the area before the late 1940's, and in part from the cesspool effluent discharged into the ground.

#### Cadmium and chromium contamination in Long Island ground water

N. M. Perlmutter, in collaboration with Maxim Lieber of Nassau County, N.Y., Department of Health and H. L. Frauenthal of Nassau County Department of Public Works (Art. 105), report that a slug of contaminated ground water in glacial outwash, which contains as much as 3.7 ppm of cadmium and 14 ppm of hexavalent chromium, extends about 4,200 feet from its source at a plating plant in South Farmingdale, Nassau County, Long Island, N.Y. The slug has a maximum width of about 1,000 feet and a thickness of about 70 feet. Part of the waste discharges naturally into a stream near the southerly end of the slug, and the remainder moves slowly downgradient as underflow in the stream valley. The contaminants, which have seeped into the ground-water reservoir for industrial recharge basins during the past 20 years, act as accidental tracers for delineating the pattern of movement in the shallow water-table aquifer.

#### Movement of acid mine-waste waters

In a study of the effects of acid mine drainage on water quality in the Beech Creek basin, central Pennsylvania, J. R. George reports that rainfall does not consistently produce "slugs" of more highly concentrated water in the drainage system. Observations of water quality at one point in the basin between June and December 1962 indicate that antecedent moisture conditions, rainfall intensity, and distribution each are significant factors in appraising the quantity of acid water and the rate at which it is washed into the surface drainage system.

#### Contamination of Lake Champlain from Saranac River

In studies carried out in cooperation with the New York State Department of Health, G. R. Ayer used glass-jug floats and temperature data to determine that contaminated water from the Saranac River emptied into Lake Champlain and moved northward past municipal beaches of the city of Plattsburgh.

#### Saline water moving upward in Roswell basin, New Mexico

G. E. Maddox reports that encroachment of brackish water into the fresh-water part of the Permian San Andres Limestone, the principal artesian aquifer of the Roswell artesian basin, has resulted from decline of artesian head caused by large-scale pumping of fresh water. Recent investigation has indicated that encroachment of brackish water may be predominantly upward, and that lateral migration is confined to local areas of greater permeability. Previously, encroachment was thought to be predominantly lateral from saline-water bodies in the San Andres east and northeast of Roswell. Marked seasonal fluctuations in chloride content of wells across a distance of several miles, increase in chloride content with depth in the San Andres Limestone, and greatest increase in chloride content of water from wells in areas of heaviest pump-

[40] Pluhowski, E. J., and Kantrowitz, I. H., 1961, Hydrology of the Babylon-Islip area, Suffolk County, Long Island, New York: U.S. Geol. Survey open-file report, 118 p.

ing have led to the conclusion that upward migration accounts for much of the brackish water. A possible source of the brackish water is the underlying Yeso Formation, which contains large amounts of salt.

#### Oil-field brine contamination in Kansas and Kentucky

Quality of water and tonnage of dissolved solids at different stages of base flow were determined by R. B. Leonard from surveys of the Walnut River, Kansas, and its major tributaries in December 1961 and April and November 1962. Chloride, which constituted about 25 percent of the dissolved solids carried by the mainstem, is derived principally from brine-saturated soil and polluted shallow ground water in or near oil fields. Local pollution of shallow aquifers by oil-field brine was determined by analyses of water from existing wells and from auger holes. Sulfate, which constituted about 15 percent of the dissolved solids in the lower reaches, is derived principally from gypsum and gypsiferous shale of Permian age, which are exposed in the western part of the basin. The waters are commonly hard to very hard.

Sulfate-chloride ratios of waters not polluted by oil-field wastes are normally greater than 1. Ratios as high as 11 were observed in tributaries draining the western part of the basin and as low as 0.03 in tributaries draining oil fields. The quality of water in most minor tributaries remains relatively constant despite variations in base flow.

According to A. M. Diaz, data from 55 sampling stations in Kansas indicate that streams in the eastern third of the State contain less dissolved solids than those in the rest of the State. This is attributed to the greater runoff in the eastern third and greater inflow of natural and oil-field brines in the western two thirds. Most Kansas streams contain less than 0.3 ppm of iron, 0.05 ppm of manganese, and 0.2 ppm of boron, but there are local exceptions.

Studies by H. T. Hopkins (1–63) in the Upper Big Pitman Creek basin near Greensburg, Ky., have shown the extent and degree of contamination of fresh ground water by disposal of brines associated with oil production. Brines were first disposed of into ponds, sinkholes, and local drainageways, but oil producers are now required to inject brines under pressure into deeper formations not used for water supply. Fresh ground water has been contaminated by downward percolation from surface disposal sites or through upward movement of injected brines that escaped through abandoned and uncased gas- and oil-test wells. Low-water salinity surveys of streams in the vicinity of the Greensburg field by R. A. Krieger indicate marked improvement in overall water quality as compared with conditions in 1959.

Investigations by the Geological Survey relating to problems of occurrence of salt water in coastal areas are discussed in Marine Geology and Hydrology (p. A125 to A127) and under Water Resources, Atlantic Coast Area (p. A21–A29) and Water Resources, Pacific Coast Area (p. A43–A50).

## DISTRIBUTION OF MINOR ELEMENTS AS RELATED TO PUBLIC HEALTH

Environmental studies have been receiving increasing attention in the field of public health in recent years. The rocks on which we live, the soils in which our foods grow, and the water that we drink are highly significant factors in the human environment, and the U.S. Geological Survey, accordingly, is participating in many investigations of how these factors affect health. The natural distribution of elements in this context is treated in the following section. Specific problems involving artificial distribution of mineral matter as related to health are treated under other topics, as follows Water Contamination Studies (p. A59), Disposal of Radioactive Wastes, (p. A57), and Studies of Atmospheric Moisture (p. A147).

#### Minor elements in San Juan County, N. Mex., and Washington County, Md.

The distribution of elements in vegetation, water, soil, and rocks of San Juan County, N. Mex., was investigated by H. L. Cannon to compare the physical environment of this county with that of Washington County, Md. The study was made for the National Cancer Institute of the National Institutes of Health, to provide data for epidemiological studies of heart disease and cancer in the two counties. The waters of San Juan County contain more iodine and sulfate than those of Washington County, but the vegetables grown there contain only one-fifth as much titanium and half as much lead as vegetables grown in Washington County. Vegetables grown on alluvium and irrigated with water from the Animas River, which receives effluent from a uranium mill at Durango, show no marked differences in minor-element content from those grown along the San Juan River, except for a sevenfold increase in strontium content.

Preliminary data from a geochemical survey of an area underlain by thin-bedded limestones and dolomites near Sharpsburg, Washington County, Md., by Sam Rosenblum and W. J. Sando, indicate generally 2- to 100-fold enrichment of most elements in the soils 2 to 10 inches below the surface, relative to the amounts in the underlying rocks. Except for calcium, magnesium, and strontium, the alkaline elements are concentrated in the soils rather in the subjacent rocks. Elements not generally found in the rocks but present in considerable amounts in the soils include boron (30–50 ppm), lanthanum (50–200 ppm), niobium (5–7 ppm), scandium (7–15 ppm), yttrium (30–100 ppm), and ytterbium (3–7 ppm). Silver was detected in the soils in amounts less than 0.7 ppm, but is generally absent in the rocks. One soil sample contained 150 ppm lithium, but this element was not detected otherwise. Although the principal radioelements, uranium and thorium, were not detected, a scintillation-counter survey indicated generally higher radioactivity in the soil than in the rock outcrops; the maximum radioactivity found was 14.4 milliroentgens per hour.

#### Distribution of natural radioactivity

Because of the known relation of artificial radiation to the incidence of cancer, the distribution of natural radioactivity is of special interest to environmental health investigators. To meet the need for information in this field the Survey is investigating the intensity of natural radiation and the distribution of radioactive minerals in the rocks, soil, and water of the United States.

Compilation by Sam Rosenblum of aeroradioactivity data of the United States is nearing completion. At least half of the 70 areas for which compilation is complete, representing 10- to 20 percent of the United States, show less than 400 counts per second of radiation attributed to the ground. Up to 5 percent of the total area included in the compilation showed radiation of more than 800 counts per second. Areas of high radiation are related to underlying crystalline rocks of granitic composition in the Appalachian and New England regions, and to uranium mineralization in the Western States.

R. C. Scott and F. B. Barker (1–62) tabulated the results (by States) of analyses of 561 ground-water samples. These results included uranium and radium concentration, content of principal dissolved constituents, and beta-gamma activity, and are accompanied by hydrologic and geologic data for each sample. The median uranium content is highest for waters of the Rocky Mountain states and lowest for those of the Atlantic and Gulf coastal plains; the median radium content is highest in waters of the Ozark–Ouachita region; and waters of the Pacific mountain belts are generally low in uranium and radium content.

#### Fluorine in ground water

A map showing the maximum fluorine content of ground water, by counties, of about 90 percent of the area of the conterminous United States, was compiled by Michael Fleischer (1–62). Areas in which the maximum fluorine content is high include most of the southwestern United States; a belt from eastern Montana through North Dakota, Iowa, Illinois, and Indiana to Ohio; and scattered smaller areas in the eastern seaboard and Central States. Areas in which ground water has a low fluorine content include the Appalachian Mountains region, the midcontinent region, and parts of the Pacific Northwest.

#### Biogeochemistry of vanadium

H. L. Cannon (1–62) reports that vanadium in small amounts is stimulating to plants but that as much as 10–20 ppm in nutrient solutions is commonly harmful. Herbs are more efficient vanadium accumulators than trees and shrubs. The vanadium content of plants rooted in calcic soils is low, and the content in plants rooted in seleniferous soils is high. Vanadium is probably essential to vertebrates, and is reported to decrease dental caries and to inhibit cholesterol biosynthesis in animals and man. Soils of many areas of the United States are low in vanadium content, and vegetation growing in them may be nutritionally deficient in this element.

#### Beryllium in coal

Peter Zubovic, Taisia Stadnichenko, and N. B. Sheffey have found that some coals in Indiana and eastern Kentucky contain 12–20 parts per million beryllium. The volatilization of beryllium as an organic complex in the burning of coal should be investigated as a possible health hazard.

#### Minor-element content of Salt Lake City municipal water supply

Osamu Hattori has determined the concentration of 17 minor elements in the Salt Lake City public-water supply, of which 7 are included in the 1961 drinking-water standards of the U.S. Public Health Service. Concentrations of these 7 elements, cadmium, chromium, copper, iron, lead, manganese, and zinc, were below the recommended limits for drinking-water in 5 major sources of supply sampled in July 1962. Although all the 17 elements analyzed for were found only in very small amounts, the relative amounts of some varied with the sources. For example, water from Deer Creek Reservoir was above the average in aluminum, copper, iron, and vanadium content; water from Little Cottonwood Creek was above the average in bismuth and molybdenum; water from City Creek was above the average in lead and cobalt; and water from Big Cottonwood Creek was above the average in nickel content. No differences in concentration of cadmium, chromium, manganese, zinc, beryllium, gallium, germanium, and titanium were noted among the five sources.

## PROBLEMS IN ENGINEERING GEOLOGY

Geology and hydrology are widely applied in construction and mining. For the most part, however, investigations are made of individual projects by the public agency or private firm doing the work. The work of the U.S. Geological Survey is directed toward investigations of the engineering geology of large areas, or the solution of fundamental problems that are common to many projects. Examples of this approach are treated in the following section and include studies of construction materials and foundation conditions in several urban areas, investigations of landslides, and studies of bumping and excessive seepage of water in mines.

### Swelling clays lacking in proglacial deposits at Seattle, Wash.

In Seattle, Wash., samples from all known fresh proglacial clay units were found by D. R. Mullineaux to have practically the same clay mineralogy, regardless of age or grain size. Investigation showed that differences in plasticity of these clays are controlled chiefly by differences in grain size. These results are of economic as well as academic importance, because liquid-limit and plasticity-index values, which are used by engineers as an index of swelling properties, for many samples are high enough to suggest the presence of swelling clay. Instead, the high index values are related to particle size rather than to the presence of swelling clays.

### Highly expansive clays at Rapid City, S. Dak.

Ernest Dobrovolny (1–63) determined that the Cretaceous shales which underlie much of the older part of Rapid City, S. Dak., particularly the Graneros Shale, are highly expansive. Samples of disaggregated air-dried material were tested with a proving-ring device (soil potential-volume-change meter) developed under the auspices of the Federal Housing Administration. Samples from the Mowry and Belle Fourche Shales develop swell-index pressures that range from 5,000 to 16,000 psf (pounds per square foot); at constant volume test values were obtained in excess of 20,000 psf. Pressures this high are indicative of very critical soil, which will cause excessive damage to structures unless special design and construction specifications are followed. Samples from the Skull Creek Shale have a range of swell-index pressure from 4,900 to 5,400 psf, low in the very critical category range. Swell-index pressures of samples from the Greenhorn Formation range from 1,200 to 2,000 psf, between the noncritical and marginal categories. Samples from the Carlile and Niobrara Formations have swell-index pressures ranging from 1,000 to 1,200 psf, in the noncritical category.

### Swelling clays at Pueblo, Colo.

G. R. Scott has found that most of the shale and surficial units at Pueblo, Colo., have only a marginal potential volume change, but that some beds of shale and bentonite have critical or very critical potential volume changes. One bentonite bed had a swell index of more than 8,000 psf. In the Pueblo area, lack of adequate drainage at the interface between permeable materials and underlying impermeable swelling soil seems to be the most common cause of foundation problems.

### Swelling soils at Stanford linear accelerator, California

Clay soils near Menlo Park, Calif., showed a change in thickness of nearly 10 mm in the top 3-foot section as a result of a 10-percent change in soil-moisture content, as compared with about 1 mm for sandy soils in the same area. These changes were demonstrated in soil-moisture observations in 1961–62, by A. O. Waananen using a neutron soil-moisture meter, and were correlated with the results of precise levels in connection with foundation and soil studies for the Stanford linear accelerator now under construction.

### Sequence of Pleistocene deposits in downtown Boston, Mass.

C. A. Kaye has found that borings and excavations on the north slope of Beacon Hill at Boston, Mass., show the same complex sequence of Pleistocene deposits and the same structural deformation as found earlier on the south slope of the hill in the excavation for an underground garage beneath Boston Common.[41] At least 3 glacial drifts and 2 separate marine clays were recognized. The structural deformation of the older drifts produced variable and unpredictable foundation conditions for the underground garage.

### Degradation of basalt on roads in Oregon

Interstitial nontronitic material in some zones of the Columbia River Basalt of Oregon are regarded by Ray Wilcox as the cause of the ultrarapid weathering of this rock and its rapid degradation when used as road aggregate and base course. This rock behaves much like the so-called "sunburner basalts," long recognized and avoided by roadbuilders in Europe. Some of the European "sunburners" have been explained as due to volume expansion in a nephelite-to-analcite alteration, but nephelite is not present in the Columbia River Basalt. The effect has recently been recognized by investigators in the Pacific Northwest, who ascribe the rapid degradation to alteration of the primary ferromagnesian minerals of the basalt to clay minerals. Probably interstitial nontronitic (and chlorophaeitic?) material is respon-

[41] Kaye, C. A., 1961, Pleistocene stratigraphy of Boston, Massachusetts: Art. 34 *in* U.S. Geol. Survey Prof. Paper 424–B, p. B73–B76.

sible for the rapid degradation and should be regarded as a late-stage deposit in the cooling history of the basalt rather than as an alteration product.

### Source of clean sand near Beltsville, Md.

A clean sand deposit in the Beltsville quadrangle, Maryland, used for asphalt paving, has been identified by C. F. Withington as a probable beach deposit of the Patapsco Formation of Upper Cretaceous age. Although the sand is of limited extent in the Beltsville quadrangle, the recognition of its origin as a beach deposit suggests that additional deposits may be found in this part of Maryland.

### Deposits of sand and gravel in western Massachusetts

G. W. Holmes has found that the deglaciation of the Housatonic drainage in western Massachusetts apparently was not complicated by many lateral shifts in drainage, by reversals in drainage, or by the lingering of many separate ice-block dams, as happened in eastern New England. As a result, coarse glacial materials of the Housatonic drainage were deposited as relatively few and commonly isolated bodies of gravel and sand, mostly in the form of kames, kame terraces, outwash terraces, and deltas. Less than a third of these deposits are being or have been exploited for construction materials.

### Comparison of shallow seismic surveys with construction records of Massachusetts highways

Comparison by Robert Mattick of shallow seismic surveys made in Massachusetts between 1949 and 1961 with highway construction records indicates that the depth to bedrock as calculated from seismic data was consistently greater than the actual depth. The 28 sites studied showed that at 2 sites the depths to bedrock were predicted with an error of less than half a foot, at 3 sites the predicted top of bedrock was 2, 8, and 10 feet above the actual top of rock, and at 23 sites the seismic depths proved to be 1 to 9 feet greater than the actual rock depths. The calculated top of bedrock for all 28 sites averaged approximately 3½ feet below the actual top of the rock. The discrepancy is due to the fact that seismic velocities in the upper few feet of bedrock were on the order of 5,000 fps (feet per second) rather than 10,000 to 16,000 fps as assumed.

### Major fault at a potential damsite on the Gunnison River, Colo.

Mapping by W. R. Hansen in the Black Canyon of the Gunnison River, Colo., disclosed a previously unknown 20-mile-long fault, which he named the Red Rocks fault. This fault has a west-northwest trend, a large pre-Jurassic displacement, a moderate Laramide displacement, and a shattered zone generally hundreds of feet wide. In one reach of the Black Canyon, where the fault trace follows the Gunnison River, poor core recovery and high water losses at a potential damsite are attributed to shattering in the Red Rocks fault zone.

### Effect of navigation dams on ground-water levels of lower Arkansas River

M. S. Bedinger, H. H. Tanaka, and L. F. Emmett are applying electric-analog models in studies for predicting the effect on ground-water levels of changes in reservoir stages behind navigation dams to be built by the U.S. Army, Corps of Engineers, on the lower Arkansas River. An initial step in this study was the preparation of a synoptic map of transmissibility of the alluvial aquifer of the lower Arkansas River valley based on aquifer tests, specific-capacity tests, and lithologic logs (Art. 107).

### Seismic investigation of coal-mine bumps, Carbon County, Utah

Sonic determinations by R. A. Black and F. W. Osterwald in the Sunnyside No. 1 mine indicated an appreciable difference in velocity between bumping and nonbumping areas. Seismic velocity in the bumping area is about 5,400 fps, whereas in the nonbumping area it is only 4,000 fps. The difference indicates either that the coals in the two areas are under markedly different stress conditions, or that they have different physical properties. Consistent results were obtained by sending signals through coal in the floors of workings and along sides of pillars rather than through the roof. It was impossible to transmit sonic signals laterally through pillars or into pillars from roofs, probably because the pillars have failed internally along shear fractures that extend upward into roofs.

A seismic monitoring system, installed by F. W. Osterwald and C. R. Dunrud near the Sunnyside coal mines, consists of a network of four vertical seismometers from which signals are transmitted to a central recording station. As many as 65 discrete events have been recorded in 1 day. Many of these events are bumps in active mining areas, others probably are roof falls in worked-out areas, and some are in unmined areas, but close to known faults. Large bumps occurred on January 17, 1963 in the Columbia mine, on March 9 in the Sunnyside No. 1 mine, and on March 12 in the Geneva mine. Their locations were accurately known and permitted accurate travel-time curves to be drawn. As a result, centers of future bumps probably can be located to within 1,000 feet of their true locations.

A recording tiltmeter has also been installed near the Sunnyside coal mines. Numerous long-period movements, with periods ranging from 30 seconds to 24 hours, have been observed. Many of these movements begin abruptly, and some consist of a series of damped sinusoidal waves of about 30-second period in addition to the mass tilting motion. The cause of these movements is not known, but they do not correspond to changes in temperature or wind velocity, or to the natural frequency of the instrument.

### Excess water in Wyoming trona mine related to heaving of mine floor

J. R. Rapp and W. T. Stuart find that in a trona mine near Green River, Wyo., water under high pressure in formations below the mined seam has leaked upward into the mine through fractures. These fractures form when the mine floor heaves at the time the load is reduced during mining. The flows decrease as the fractures are closed through compression caused by weight of the overburden as caving closes the mine openings. A network of wells has been proposed to relieve the hydrostatic pressure and thereby decrease the possibility of a breakthrough of water into the mines.

### Seepage in Wisconsin zinc-lead mines related to synclinal structures

In the zinc-lead mines of southwestern Wisconsin, C. L. R. Holt found that the largest flows of water in the mine drifts were associated with synclinal structures and highly fractured ore zones in dolomite. Ground water was found to be moving upward into the mined areas from the underlying St. Peter Sandstone.

### High artesian head in abandoned Pennsylvania coal mines causes seepage problems

Near Pittston, Pa., measurements in abandoned anthracite mines indicate hydrostatic pressures above the land surface. To prevent flooding of basements from seepage, a 48-inch borehole was drilled into a mine to permit overflow and reduction of the head. The overflow is regulated according to the discharge of the Lackawanna River available for dilution of the mineralized acid mine water.

### Landslides in the Orinda Formation east of San Francisco Bay

A study by D. H. Radbruch and L. M. Weiler (1–63) of 195 landslides in a suburban area underlain by the Orinda Formation, east of San Francisco Bay, indicates that exposure and relation of bedding and joints to hill slopes are important controls. On natural slopes, sliding is most common on northeast-facing hillsides where the bedding dips opposite to the slope. In cuts, sliding commonly occurs on joint planes as well as bedding planes.

### Landslides near Gardiner, Mont.

Geologic mapping in the Gardiner, Mont., quadrangle by H. A. Waldrop and H. J. Hyden (1–63) has shown that an area of about 5 square miles southwest of Gardiner consists not of glacial drift, as previously supposed, but of glide blocks, slumps, and earthflows of interglacial and postglacial age.

## PROBLEMS IN ENGINEERING HYDROLOGY

## *LAND SUBSIDENCE*

Compaction of aquifer systems resulting from decline of artesian pressure has been observed in many widely scattered areas. This phenomenon is significant not only because of the resulting land subsidence, but also because the compaction is a measure of the amount of ground water yielded from storage in the aquifer system. Specific investigations of land subsidence are in progress in the San Joaquin and Santa Clara Valleys, Calif., and the Houston–Galveston area, Texas. In addition, subsidence is being investigated as a facet of ground-water problems at Las Vegas, Nev., in southern Arizona, and at Denver, Colo.

Another type of subsidence, that due to oxidation of peat at land surface, is described also.

### Land subsidence exceeds 1 foot per year in central California

In the Los Banos–Kettleman City area on the west side of the San Joaquin Valley, Calif., analysis of releveling by the U.S. Coast and Geodetic Survey indicates that land subsidence from December 1959 to March 1963 has been as much as 4 feet. At one site, where subsidence from February 1960 to March 1963 as determined by the releveling was 3.45 feet, measured compaction of the deposits to a depth of 2,000 feet was equal to 98 percent of the measured subsidence.

In the Los Banos–Kettleman City area, the subsidence per foot of artesian-head decline (specific subsidence) and the subsidence per foot of artesian-head decline per foot of thickness of the aquifer system (specific compaction) were determined for the 1943–60 period by W. B. Bull. In most of the area the specific subsidence has ranged between $2\times10^{-2}$ and $8\times10^{-2}$ and specific compaction has been greater than $3\times10^{-5}$.

R. H. Meade (1–63) has analyzed compaction of the unconsolidated silty alluvium in the subsiding Los Banos–Kettleman City area. Regression equations that describe the average rate of reduction of pore space in response to increase of effective overburden loads from 10 to 70 kg per cm$^2$ indicate that the rate of change of void ratio with effective overburden load in sandy and clayey silts is about $-0.40$ and in silty sands may be near $-0.20$.

Compaction recorders operated in the Arvin–Maricopa area at the south end of the San Joaquin Valley, where the rate of subsidence accelerated in 1959–62, indicate that most, if not all, of the subsidence is caused by compaction of water-bearing deposits as the artesian head is reduced by pumping. At one site, measured compaction of the deposits to a depth of 810 feet is equal to three-quarters of the measured land subsidence; one quarter of the subsidence is attributed to compaction below this depth (Art. 47). Deep water wells in this area tap deposits to a depth of 1,500 feet.

#### Rate of subsidence increasing at south end of San Francisco Bay

In the Santa Clara Valley, Calif., the bench-mark net was partially releveled by the Coast and Geodetic Survey in February 1963. Analysis of results by J. F. Poland indicates that subsidence has accelerated greatly, compared with the rate from 1954 to 1960. This acceleration is greatest in the city of San Jose, where many bench marks have subsided more since autumn 1960 than from 1954 to 1960, as a result of accelerated decline in artesian head. Bench mark P7 in San Jose subsided 1.67 feet from October 1960 to February 1963; total subsidence of this bench mark from 1912 to February 1963 has been 11.06 feet.

Measured compaction of water-bearing deposits to a depth of 1,000 feet (maximum depth of water wells) from October 1960 to February 1963 at sites in Sunnyvale and San Jose was about equal (within 5 percent) to the land subsidence for the same period as measured by releveling.

Utilizing results of consolidation and other physical tests on cores from the artesian aquifer system in the Santa Clara Valley, Calif., and records of change in artesian pressure since 1915, J. H. Green (1–62) has shown that, at one location, the compaction of the deposits computed from these data agrees closely with land subsidence as measured at surface bench marks. At a second location, computations indicate additional subsidence of 3 to 4 feet eventually, if artesian pressure remains at the 1960 level. Green's analysis of subsidence during two periods of artesian-pressure decline in the Santa Clara Valley shows that during the initial decline of pressure the coefficient of storage at a site in San Jose was about 40 times as great as during a subsequent pressure decline through the same depth range.

#### Several feet of subsidence reported at Las Vegas, Nev.

In the Las Vegas area, Nevada, recent protrusion of well casings suggests that several feet of subsidence has occurred since 1950, presumably associated with aquifer-system compaction. Up to that time, subsidence in Las Vegas had not exceeded 1 foot and in part represented regional subsidence due to loading by Lake Mead. Linear cracking of the land surface, which may be related to the subsidence, has ruptured pavements. Such cracking has not occurred in areas subsiding due to aquifer-system compaction in the San Joaquin or Santa Clara Valleys in California, but has occurred in the subsiding Houston area, Texas.

#### Land subsidence and earth fissures in southern Arizona

Earth fissures at six sites in southern Arizona have been descibed by G. M. Robinson and D. E. Peterson (1–62). In part these are in or near areas irrigated with ground water; most are in valley alluvium, but at least one area of fissures is in semiconsolidated sedimentary rocks (Black Canyon area north of Phoenix); the specific cause or causes of the fissures are not known. The same publication reports land subsidence of as much as 3.6 feet due to ground-water pumpage in the Eloy–Pichacho basin, about 50 miles northwest of Tucson.

#### More than a foot of subsidence reported at Denver, Colo.

Preliminary results of investigations in the Denver basin, Colorado, by G. H. Chase indicate that as much as 1½ feet of subsidence has occurred. Precise leveling by the Coast and Geodetic Survey at four times between 1899 and 1956 defines subsidence of nearly 1 foot in an area with a radius of about 10 miles, centered at Denver. Within that area the artesian head has declined as much as 600 feet since 1890. The artesian aquifers of the Denver basin extend to depths as great as 2,500 feet and include three principal water-bearing zones: an upper zone of alluvial deposits, and two lower zones of estuarine and marine deposits of Late Cretaceous age.

#### Clay mineralogy similar in subsiding areas in Texas and California

The principal clay minerals in the upper 900 feet of sediments at Clear Lake, Tex., in the Houston-Galveston subsidence area, have been determined by J. B. Corliss and R. H. Meade. They are, in decreasing order of abundance, montmorillonite, illite, chlorite, and a kaolinite-type mineral. Montmorillonite makes up at least half the assemblage in all eight samples tested. The assemblage (with predominant montmorillonite) is similar to that found in the upper Cenozoic sediments that underlie the two major areas of land subsidence in the San Joaquin Valley, Calif.

An automatic liquid-level recording tiltmeter developed for measurement of micromovements of the land surface in subsidence investigations is described on page A183.

#### Differential subsidence in the Sacramento–San Joaquin Delta

Comparison of topographic mapping of 1906–08 with that of 1952 in the peatlands of the Sacramento–San Joaquin Delta by G. H. Davis (Art. 101) shows that local relief of more than 15 feet has developed on formerly level terrain. Relative subsidence of peat soil through surface wastage is the cause; soils of high mineral content marking old channels and dunes stand out as ridges.

## ARTIFICIAL RECHARGE

Artificial recharge of aquifers is desirable in many areas subject to marked seasonal variations in the supply and demand for water. The objectives of U.S. Geological Survey investigations in this field are to evaluate the potentialities and limitations of recharge by surface spreading and through wells.

### Snake River basin

Artificial recharge of ground water in the Snake River Plain, Idaho, using surplus floodwaters is feasible, according to M. J. Mundorff and others.[42] Studies at sites located near the east end of the plain, a few miles west of Idaho Falls, and along the Milner-Gooding Canal, show conditions favorable for recharge to the underlying basalt by water spreading. Recharge effectiveness is demonstrated by the recharge from irrigation, approximating 3½ million acre-feet a year, several times that available for artificial recharge. The downward trend in the water table would not be reversed by the artificial recharge because of increasing demands for irrigation with ground water, The added recharge, however, would permit pumpage of about twice the quantity added (assuming 50 percent consumptive use) without additional water-table decline.

### Oregon and Washington

Don Price reports that as much as 17,000 acre-feet of water is recharged artificially to ground-water bodies in Oregon and Washington by spreading in surface basins and by injection through wells. The principal purposes of the artificial recharge are the conservation of the ground water or some property of it, such as heat content, for later recovery, but correlative benefits are the disposal of unwanted water. Few of the 23 known artificial-recharge installations were operated without trouble in 1962. Major problems are related to subsurface injection through wells, especially injection of exhaust water from air-conditioning systems, and included (1) reduction of intake due to the introduction of air bubbles, sediment, or nuisance bacteria with the recharge water, and (2) changes in natural ground-water temperatures by injection of waters having much higher or lower temperatures. The current problems relating to injection through wells could be improved by (1) design of installations that would minimize the entrance of air into the system and keep in solution any air that is already dissolved in the recharge water; (2) treating the recharge water prior to injection to prevent growth of nuisance bacteria; (3) adequate spacing, or placement in hydraulically separate aquifers, of wells used to inject water of widely different temperatures.

### Injection of water through wells in permeable basalt

Artificial-recharge experiments by B. L. Foxworthy showed that water could be successfully injected through a well into a basalt aquifer, at The Dalles, Oreg. Recharge water tended to settle to the bottom of the highly permeable aquifer because it was much colder than the native ground water. About 81 million gallons of water was injected during 4 periods of recharge ranging from 8 hours to more than 14 days. The recharge well was successfully redeveloped by intermittent pumping after injection was stopped.

### Recharge through wells in the Grand Prairie, Ark., area

R. T. Sniegocki (1–63) reports that two differently constructed recharge wells were used to make 23 recharge tests in the Grand Prairie region, Arkansas, using surface water treated in various ways. Treated surface water was used in early tests, but in some of the later tests the degree of water treatment was reduced. Slightly more than 23 million gallons of water was recharged during the test series.

A prerequisite to successful recharge through a well at the test site was the availability of a supply of water of very low turbidity with few microorganisms. The major factor determining the total recharge cost was the cost of treating an injection supply to obtain water with low turbidity and few microorganisms.

A coarse-grained media filter might be used to reduce water-treatment costs with some waters. However, the results of filtration tests at the recharge site were unsatisfactory and apparently were caused by unknown filtration characteristics of the recharge supply.

## EVAPORATION SUPPRESSION

One of the most promising possibilities for increasing water supplies in arid areas is by reducing evaporation losses from surface reservoirs. One means of achieving this is by greater use of ground-water storage, but exciting new approaches are also being applied to existing surface reservoirs. Results of two current U.S. Geological Survey investigations are reported.

### Polyethylene covers for small ponds

G. E. Koberg reports that the method of using plastic films on small stock ponds may be feasible. During a period of 11 months, 30 percent of the surface area of a 1-acre pond was covered by a 4-mil film of black poly-

[42] Mundorff, M. J., Crosthwaite, E. G., and Kilburn, Chabot, 1963, Ground-water for irrigation in the Snake River basin in Idaho: U.S. Geol. Survey Water Supply Paper 1654. [In press]

ethylene. Use of the film reduced evaporation 22 percent and saved 1.4 acre-feet of water. The temperature of the water in the uncovered portion was the same as that of a nearby pond during the test period.

### Evaporation greatly reduced by bubbler method of mixing water

An investigation by G. E. Koberg in collaboration with the Escondido Mutual Water Co. demonstrated the feasibility of reducing evaporation by mixing the cold and warm water in Lake Wohlford, Calif. Preliminary results of this investigation indicate that the evaporation was reduced 15 percent for the period May through July 1962. The water was mixed by injecting 210 cfm of free air at a point 40 feet below the surface of the lake. Mixing throughout the lake was most efficient when the difference in temperature between the cold and warm water was greatest. Air injection also raised the dissolved-oxygen content of the water of the lake and improved the taste and odor of the water.

## FLOODS

Floods are among the most severe of natural disasters and each year claim many lives and cause untold damage. The flood studies of the U.S. Geological Survey are not limited merely to gaging flood flows, but include interpretation and reporting of the magnitude and extent of floods, appraisal of their frequency, and evaluation of the effects of storage and protection works.

### Floods in the Kentucky River and Green River basin, February-March 1962

Extreme flooding occurred in several parts of Kentucky in late February and early March 1962. During the period February 27 to March 2, new peak discharges or stages were established at one or more gaging stations in each major stream basin of the State. The hardest-hit areas included the mid and lower reaches of the Kentucky River and tributaries, and the Green River basin.

The Kentucky River at lock 10 near Winchester crested at 36.07 feet on March 1, exceeding the flood of 1913 by 1.0 feet. Three gaging stations in the basin of the Red River, a tributary of the Kentucky River above lock 10, reached new peak stages and discharges.

New peak discharges were established at 6 gaging stations in the Green River basin. The Munfordville station reached 76,800 cfs, gage height 57.72 feet, as compared with the previously known high of 67,000 cfs, gage height of 54.0 feet, in 1913. At three points in the basin of the Barren River, a tributary of the Green River, peak flows were as much as 50 percent greater than those recorded in the past 24 years.

### Cloudburst flooding at Boise, Idaho, August 1959

Interest in runoff from cloudburst floods was heightened by the surprisingly large peak discharges resulting from a thunderstorm which struck the foothills northeast of Boise, Idaho, on August 20, 1959, sending heavily debris laden flood waters into the city and over adjacent areas to the east. C. A. Thomas reports that peak-discharge rates ranged from 132 csm (cubic feet per second per square mile) from 12 square miles in Cottonwood Creek, the largest basin measured, to 5,380 csm from 0.39 square mile, the smallest basin measured. Much of the watershed has been denuded by recent fires and presumably this was a factor in producing high runoff and erosion.

Of special interest was the drastic flattening of peaks as they moved downstream, with resultant decrease in the unit-discharge rate. For example, the Cottonwood Creek peak was only one-sixth the sum of the peaks of two tributaries upstream which have combined drainage areas less than one-third as large. Also of interest was the recurrence of damaging, though less severe, floods from the same areas twice within a little more than a month after the major flood.

### Snowmelt flooding in California

A record-breaking drought in California ended abruptly on January 29, 1963, when rains of up to 20 inches melted the snowpack and caused floods greater than ever recorded at some stations in the northern Sierra Nevada. Flooding extended into Nevada.

### Evaluation of February 1962 floods in Idaho and Nevada

Floods of February 10–15, 1962 were the highest known on many streams in southern Idaho and northeastern Nevada according to C. A. Thomas and R. D. Lambke (1–62). Runoff was greatest from watersheds at altitudes ranging from 4,500 to 6,500 feet, and peak discharges from small streams rank among the highest snowmelt runoff ever recorded in the area. Some of the indicated recurrence intervals exceed 100 years. The floods resulted from an extended period of above-freezing temperatures and prolonged moderate rainfall, an extensive area of snow at low altitudes, and deeply frozen ground. An important factor in the flooding was the ice-sealed condition of the ground, which resulted in the unfamiliar sight of ponded or flowing water in areas of highly permeable lava.

### Flood-frequency relations for Maryland streams

J. M. Darling has prepared a guide for developing flood-frequency curves for any stream in Maryland. Composite frequency curves were developed for three regions, expressing the relation of mean annual floods to floods having recurrence intervals from 1.1 to 50 years. Other curves indicate the magnitude of the mean annual flood (a flood having a recurrence interval of 2.33 years) for five hydrologic areas of the State. By combining the two types of curves, a flood-frequency relation may be developed for any site in the State, within the range of drainage areas delimited by the data.

**Flood-frequency relations for Louisiana streams**

V. B. Sauer has updated Cragwall's (1952) report on floods in Louisiana on the basis of an additional 10 years of record as well as records now available at many new gaging stations and at many crest-stage stations. The frequency relations are better defined than the initial study.

The State is divided into four flood-frequency regions. The magnitude of floods is determined as a ratio of the mean annual flood in the four defined regions. A significant increase of flood potential in the Calcasieu basin is defined by this report, as compared with the potential given in Cragwall's report. The mean annual flood is defined in relation to drainage area. Statistical tests were made using other natural definable parameters; however, none was found that significantly improved the relation defined by drainage area.

**Flood-frequency relations for streams in eastern Washington**

Crest-stage gage records were used by B. N. Aldridge and J. C. Blodgett to evaluate regional flood-frequency relations for the arid and arid-transition zones of eastern Washington. Records from these stations have been used in conjunction with those from recording stations to develop curves that show the discharge for any magnitude flood for drainage areas of less than 100 square miles.

Thunderstorm floods were studied separately from those resulting from snowmelt. The snowmelt study shows that in the arid-transition zone where the native vegetation is grass, there is some flow each year and the discharge of any flood magnitude varies according to the 0.7 power of the drainage area. The same relation holds for drainage areas of all sizes as long as closed basins constitute only a minor portion of the drainage area. Data were not sufficient to define the relation of discharge to drainage area for the arid region where the native vegetation is sagebrush. Thunderstorms, although common to the area, are rare on any particular stream. By using a station-year method, a curve was developed for determining frequencies of flood discharges resulting from thunderstorms. This study utilized miscellaneous measurements as well as records from crest-stage gages.

**Flood-frequency relations for streams in San Diego County, Calif.**

Flood-frequency relations for the western slopes of San Diego County were estimated by L. E. Young and H. A. Ray, using drainage area and a basin-shape factor to prepare maps of areas that would be inundated by 50- and 100-year floods.

**Effects of storage on peak discharges in New Jersey**

Flood peak discharge of New Jersey streams is significantly affected by storage in lakes, ponds, and swamps according to D. M. Thomas. Storage areas of 20 percent of the total drainage area will reduce the peak discharge to one-fourth that of basins of equal drainage area but with only 2 percent lakes, ponds, and swamps.

**Flooding at Chattanooga, Tenn.**

Study of flood discharges and profiles along the lower 10 miles of Chattanooga Creek at Chattanooga, Tenn., reported by A. M. F. Johnson and W. J. Randolph (1–62), shows that high stages of the Tennessee River are the predominant influence in flood profiles of most of the 10-mile reach. Headwater floods, however, should be considered in land-use planning throughout the whole reach, and are a major influence on flood heights in the upper third of the reach.

**Effect of urbanization on floods in northern Virginia**

Urbanization appears to have three primary effects on floodflow in Fairfax County, Va., according to D. G. Anderson: (1) reduced infiltration increases flood volume, (2) complete sewering of basins reduces lag time by as much as 85 percent, and (3) urbanization changes the flood-frequency distribution. The degree of effect decreases with increasing flood magnitude.

**Flood hydrology of southwestern Mississippi and southeastern Louisiana**

F. N. Hansen analyzed more than 900 flood hydrographs from 304 station years of record to determine rainfall-runoff relations and to develop unit hydrographs in southwestern Mississippi and southeastern Louisiana. Although the 60 inches of annual rainfall is nearly uniformly distributed during the year, about a quarter of the floods occurred in March, more than half from February to April, and less than a tenth in October. Direct runoff of more than 3 inches is not infrequent; separate floods with 6 to 7 inches direct runoff have been recorded.

**Estimating flood magnitude in Kentucky streams**

The magnitude of a flood of a selected frequency at most sites in Kentucky may be determined by methods outlined by J. A. McCabe (1–62). He used composite frequency curves for 2 flood regions and 2 main-stem streams and curves showing variation of mean annual flood with either drainage area or river miles for 6 hydrologic areas and 5 main-stem streams.

### Extending small-area flood records in Alabama

Using a graphical multiple regression of peak flow versus rainfall characteristics derived from 4 years of record for a 12-square-mile watershed (Jones Creek near Epes, Ala.), L. B. Peirce synthesized an array of annual floods from a 58-year record of storm rainfall. Areal rainfall characteristics in Alabama indicate that under favorable conditions the method can produce flood-frequency curves of practical use for many small watersheds in the State. Best results are for relatively impermeable and unretentive watersheds and for floods occurring in winter and spring.

### Flood maps of urban areas

Flood-inundation maps showing the limits of past inundations, flood profiles, stage-frequency relations, and descriptive text have been published as Hydrologic Investigations Atlases (HA) for the following areas during the current year: Warren, Ohio (HA-51); Youngstown, Ohio (HA-56); Tampa, Fla. (HA-66); Mount Clemens, Mich. (HA-59); Bayamon and Catano, P.R. (HA-77); Des Moines, Iowa (HA-53); Fremont, Calif. (HA-54); Atlantic City, N.J., and vicinity (HA-65); Wichita, Kans. (HA-63); Arlington Heights, Ill. (HA-67); and Elmhurst, Ill. (HA-68).

### Nationwide flood reports

A series of reports are in preparation to provide a basis for estimating the magnitude of floods of selected frequency at any site. The reports contain descriptions and lists of peak stages and discharges for all gaging stations that are not materially affected by storage or diversions, and that have 5 years or more of flood record. Publication will be in 19 parts corresponding to the drainage-basin subdivisions used by the Geological Survey. Six parts have been completed, and are awaiting printing.

# REGIONAL GEOLOGY

Much of the geologic and geophysical work of the U.S. Geological Survey consists of the mapping of specific areas, mostly for publication in quadrangle maps at scales of 1 : 62,500 and 1 : 24,000. Some of these studies are for the purpose of extending the detailed geologic knowledge in areas of known economic interest; some are to gain detailed knowledge at localities or areas for engineering planning or construction. Still other mapping studies are carried on with paleontology, sedimentary petrology, or some other specialized topic as the primary objective.

The systematic description and mapping of rock units to show local and regional relations likewise constitute a major scientific objective. Mapping the geology of the United States is a mandate of the Organic Act establishing the Geological Survey, and the completion of geologic maps for the country at scales that will fulfill foreseeable needs and uses is a long-range goal. A summary of recent results of this mapping, especially in the fields of stratigraphy, structural geology, and regional geophysics, is discussed here according to subdivisions of the conterminous United States shown in figure 2.

## MAPS OF LARGE REGIONS

Preparation of geologic maps of large regions or of national scope is one of the functions of the U.S. Geological Survey. The maps depend on data from mapping and topical studies by Geological Survey personnel, on published data, and on unpublished data generously provided by State geological surveys, private companies, and universities. Some maps of this type are prepared and published by the Geological Survey in collaboration with national and international scientific organizations.

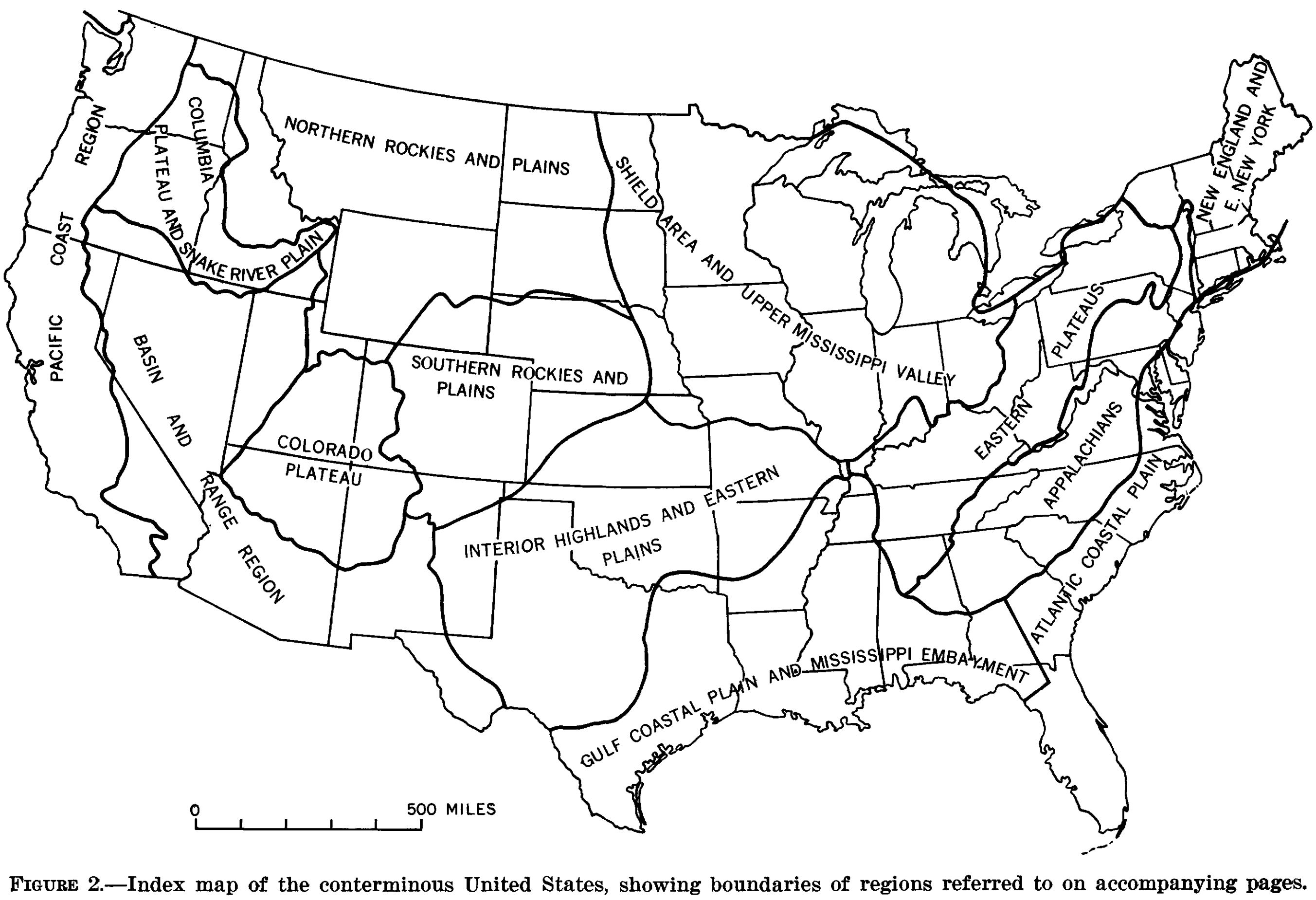


FIGURE 2.—Index map of the conterminous United States, showing boundaries of regions referred to on accompanying pages.

Maps in preparation include:

1. Geologic map of North America, scale 1:5,000,000. This is being compiled by a committee of the Geological Society of America, E. N. Goddard, University of Michigan, chairman, and is to be published by the Geological Survey.
2. Basement map of North America from latitude 20°–60° N., scale, 1:5,000,000. This structure map of the basement is being compiled by the Basement Rock Map committee of the American Association of Petroleum Geologists, under the direction of P. T. Flawn, University of Texas, and is to be published by the Geological Survey. A second phase of the work, the Basement Rock Map of the United States, is sponsored by the Advanced Research Projects Agency of the U.S. Department of Defense. Compilation is under the direction of W. R. Muehlberger, University of Texas. This second map will show the distribution of lithologic types of buried basement rocks. Under the direction of R. W. Bayley, the Geological Survey has started compilation of a companion map, scale 1:2,500,000, showing basement rocks that are exposed at the surface.
3. Absolute-gravity map of the United States, scale 1:2,500,000. This map has been compiled by the American Geophysical Union, Committee for Geophysical and Geological Study of the Continents, G. P. Woolard, University of Wisconsin, chairman, and is being prepared for publication by the Survey.
4. Tectonic map of North America. This map is being compiled for the Subcommission for the Tectonic Map of the World, International Geological Congress, under the direction of P. B. King of the Survey. Hand-colored manuscript copies of the preliminary version of this map were exhibited in Paris at the December 1962 meeting of the International Commission for the Geologic Map of the World.

### Paleotectonic maps

Facies distribution and other elements of ancient geography constitute the subject matter of important sections in the paleotectonic map series. The isopach and lithofacies maps illustrate the results of sedimentation during certain intervals of time; the environmental maps show the distribution of sedimentary facies and the relations of land to sea at particular moments in time. Also significant in the field of sedimentology are the recently devised interpretive maps, developed from the other more objective types, but portraying more fully such features of the structural framework as positive source areas and areas of sediment accumulation. These maps likewise summarize available data on directions of sediment transport.

The paleotectonic map program has been progressing steadily, with studies of the Permian System now completed and being processed for publication. Basic maps for the Pennsylvanian and Mississippian Systems are in different stages of compilation. In the synthesis of the Permian, notable contributions to sedimentology include (1) a map showing salt distribution in the midcontinent region for each of the principal parts of the period, (2) maps illustrating the type and maximum extent of chemical deposits for selected times during the Permian, (3) maps portraying the relations between phosphate and chert, the configuration of land and sea, and the inferred current directions at the time of accumulation.

### Ancient lake deposits in the Western States

J. H. Feth has compiled a series of four maps showing the distribution of ancient lake deposits in the 11 coterminous Western States, one each showing pre-Tertiary deposits; Paleocene and Eocene deposits; Oligocene, Miocene, and Pliocene deposits; and Pleistocene deposits. A table provides the name and age of the deposits and the principal literature references. An annotated bibliography summarizes the principal discussions of the deposits shown on the maps, the economic products derived from the lake deposits, and the criteria by which the deposits can be identified in the field. A map showing Tertiary lake deposits has been published (Feth, 1–63).

### Distribution of rock-salt deposits in the United States

An outline map of the United States (scale 1:10,000,000) showing the distribution of rock-salt deposits and mines in the conterminous United States is included as an index map by Pierce and Rich (1–62) in their report on rock-salt deposits as possible storage sites for radioactive waste materials (p. A59). The ages of the rock-salt deposits range from Silurian to Pliocene (?).

## COASTAL PLAINS

Growth of population and of industry on the Atlantic Coastal Plain, the Gulf Coastal Plain, and the Mississippi Embayment has resulted in an increased use of geologic studies in solving engineering problems of urban and regional planning, such as the underground storage of gas. The rocks of the region are of especial interest for interpreting the geologic history of the continental shelf and the Gulf of Mexico. Moreover, on the coastal plain, the results of depositional and other geologic processes may be studied free from the effects of regional metamorphism or major structural deformation.

## ATLANTIC COASTAL PLAIN

### Stratigraphic studies in New York and New Jersey

Seventy-five species of Upper Cretaceous Foraminifera recently collected from southern Suffolk County, Long Island, N.Y., will be described and illustrated in a report by N. M. Perlmutter and Ruth Todd. The fossils occur in a greensand unit 200 feet thick, which is the uppermost part of a 1000-foot sequence of beds of Cretaceous age that were formerly assigned to the Magothy(?) Formation. The authors believe that the greensand beds are correlative with the Monmouth Group of New Jersey, and they infer that the remaining Cretaceous sequence below is correlative with the Matawan Group and the Magothy Formation, although further work is needed to differentiate the latter units.

Quaternary, Tertiary, and Cretaceous sediments totaling 3,798 feet and overlying 93 feet of biotite gneiss were penetrated by a testhole at Island Beach State Park in Ocean County, N.J. Details of the section penetrated are discussed on page A24 and in Article 26.

In southern New Jersey, J. P. Owens has extended the Tertiary–Cretaceous boundary 70 miles along strike from Roosevelt to Woodstown, N.J., and has demonstrated that from northeast to southwest, progressively older Cretaceous beds are in contact with the overlying Hornerstown Sand of Paleocene age.

A recent examination of a microfauna by J. F. Mello from the *Exogyra ponderosa* zone collected by J. P. Owens at Auburn, N.J., reaffirms L. W. Stephenson's (1942) Taylor age assignment based on macrofossils.

### Stratigraphy and structure in North Carolina and Virginia

In northeastern North Carolina, marine sediments containing lower Cretaceous Ostracoda and Foraminifera were penetrated in numerous wells; in most wells these sediments lie beneath sandy clay beds rich in siderite grains and above metamorphic basement rocks. The top of the marine zone ranges from 106 to 713 feet below land surface. The attitude of both the sideritic and the fossiliferous beds defines the western flank of a basin whose axis extends northeastward across the coastal plain in central North Carolina and adjacent southeastern Virginia. The eastern flank is indicated by other wells farther east that penetrate Cretaceous sections at depth, suggesting a flattening or slight reversal of dip. Dips within the basin are gentle but discernible and probably are related to structures in the continental shelf, according to P. M. Brown, J. E. Johnston, and H. R. Bergquist (1–63).

### Evidence of volcanism in South Carolina

The youngest vestiges of igneous activity in South Carolina are thought by W. C. Overstreet and Henry Bell, 3d, to be beds of bentonite of Eocene and Miocene age in the Atlantic Coastal Plain in Orangeburg and Calhoun Counties. The bentonitic beds and the included, sharply euhedral grains of zircon were first recognized by H. S. Johnson, Jr. The zircons are unlike the common rounded detrital grains in the sedimentary rocks of the Atlantic Coastal Plain. The shape and mode of occurrence of the euhedral zircon crystals suggests that they are of primary igneous origin, and probably are pyroclastic. Inasmuch as the Tertiary sedimentary rocks of the Atlantic Coastal Plain in South Carolina are not known to be intruded by dikes or volcanic vents, the source of the volcanic ash and euhedral zircon must be sought either in guyots off the present coast or in pipes and dikes inland from the northwestern margin of the coastal plain sediments. Statistical analysis of the distribution by size of the populations of euhedral zircon grains in the Tertiary bentonites might show the direction in which the sources of the ash lay.

The presence of a previously postulated mantle of saprolite overlying the buried crystalline rock at the Savannah River Plant in Aiken County, S.C., has been confirmed by a study of geophysical logs, lithologic samples, and analyses of water from the present series of test holes drilled within the plant site.[43] One of the test holes near the Barnwell–Allendale County line struck a sequence of siltstone, sandstone, and conglomerate of Triassic age at a depth of 1,012 feet. Seven other test wells bottomed in metamorphic basement rock, a chlorite-hornblende schist. Triassic basins have been found farther to the northeast and possibly some are present to the southeast near the coast, but none were previously known to underlie this area of the coastal plain.

An entrained gas was discovered in water from a 1,900-foot test well penetrating the buried basement rock at the Savannah River Plant. An analysis of the gas showed the following composition: 94 percent nitrogen, 5 percent helium, 1 percent argon, and negligible amounts of carbon dioxide and oxygen. Not only the occurrence, but also the comparatively high percentage of helium, is unusual for this geologic terrane. The presence of the gas is considered of little economic significance because of the limited reservoir capacity of the basement complex.

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[43] Siple, G. E., 1962, Ground water investigations in South Carolina: South Carolina State Devel. Board, Div. Geology, Geol. Notes, v. 6, no. 2, March–April.

## GULF COASTAL PLAIN AND MISSISSIPPI EMBAYMENT

### Stratigraphic studies

While conducting subsurface investigations of Cretaceous rocks in the eastern Gulf Coastal Plain, E. R. and P. L. Applin discovered a species of Foraminifera in southern Mississippi that provides a basis for differentiating rocks previously designated by some geologists as "Washita-Fredericksburg undifferentiated." This discovery may assist subsurface geologists in tracing the so-called deep Edwards trend, which is an important oil-producing zone in Texas, eastward into the eastern Gulf Coastal Plain.

As a study of Oligocene molluscan fauna of Mississippi by F. S. MacNeil progresses, cumulative information points more and more to an Oligocene age for the Vicksburg Group rather than the Miocene age recently proposed by a British worker. According to MacNeil, the Red Bluff Clay is a correlative of the Rupelian of Europe.

Evidence obtained from geologic studies by Monroe and others [44] of core samples from pre-Selma Cretaceous rocks in western Alabama shows that many of the strata accumulated in water of low salinity. A review of geologic events suggests that the Sequatchie River and the eastern segment of the Tennessee River once drained southwestward to the Gulf of Mexico approximately along the present courses of the Warrior and Cahaba River valleys, respectively, in Alabama.

### Geohydrologic studies

In conjunction with the geohydrologic environmental study of the Sparta Sand (middle Eocene), J. Norman Payne reports that isopach maps of the Cane River, Sparta, and Cockfield Formations for central and northern Louisiana, southern Arkansas, and southern and central Mississippi indicate that the greater thicknesses of the Cane River and Cane River equivalents are in Lincoln, Drew, and Desha Counties, Ark., and Bolivar, Sunflower, and Washington Counties, Miss. The greater thicknesses of the Sparta are in Madison and Tensas Parishes, La., and Warren and Claiborne Counties, Miss., and those of the Cockfield are in Vernon and Rapides Parishes, La. The isopach maps also indicate growth of various structural features, such as the Jackson dome and Desha basin, during Cane River and Sparta time. Sand-percentage maps of the Sparta and the Cockfield Formations for the study area show a channel-like development of areas of high sand percentage that has a general north-south lineation, and an overall pattern similar to the channel pattern of the present Mississippi delta.

Payne further reports that the degree of fresh-water saturation of the Sparta Sand shows remarkably good conformity with the sand-percentage map of the formation. This suggests that the lower the sand concentration the less perfect the interconnection of individual sand bodies and consequently the greater the retardation of the flushing action. The transmissibility on the other hand is related not only to the percentage concentration of the sand but also to the unit thickness of the sand bodies. From a map of northern Louisiana showing the maximum sand-unit thickness distribution and the estimated transmissibility of the Sparta, it seems that where sand-unit thicknesses are relatively large, 80 to 100 feet or more, permeabilities can be expected to be reasonably high (over 400 meinzers). Sand percentage and maximum sand unit thickness maps may prove to be extremely useful as general exploration maps in the search for adequate ground-water supplies.

## NEW ENGLAND AND EASTERN NEW YORK

Cooperative geologic-mapping programs are being carried on with the Commonwealth of Massachusetts (in part in conjunction with the U.S. Bureau of Public Roads) and with the States of Rhode Island and Connecticut. Geophysical and geochemical surveys, and field studies related to mineral deposits, are in progress in these States and in Maine, New Hampshire, and Vermont.

### Geologic and geophysical studies in Maine

Richly fossiliferous tuffaceous mudstone, basalt conglomerate, and breccia near Ashland are being studied by R. B. Neuman (Art. 30). The principal fossils are Welsh-Baltic brachiopods of Caradocian (Middle Ordovician) age. The strong European affinities of the faunas of these and other Ordovician volcanic rocks in Maine suggest volcanic islands as possible migration routes between Europe and North America.

Silurian coral faunules have recently been described from Maine by E. C. Stumm (1–62) and from Quebec by W. A. Oliver, Jr. (1–62, 3–62). According to Oliver the corals are a mixture of North American and Western European types and represent the first suggestion of an extensive North American coral fauna like that of Gotland, Sweden. More recently, elements of this fauna have been collected from the Cobleskill Limestone in New York and from the lower part of the Keyser Limestone in West Virginia.

Twelve Silurian graptolite localities in the Houlton and Smyrna Mills quadrangles in southern Aroostook

[44] Monroe, W. H., Bergenback, R. E., Sohl, N. F., Applin, E. R., Leopold, E. B., Pakiser, H. M., and Conant, L. C., 1963, Studies of pre-Selma Cretaceous core samples from the outcrop area of western Alabama: U.S. Geol. Survey Bull. 1160. [In press]

County, studied by W. B. N. Berry and Louis Pavlides, range from middle Llandovery through early Ludlow in age. Thus, all three epochs of the Silurian are represented in a relatively small area in northeastern Maine; this region may eventually yield a graptolite sequence for the United States.

The Kennebago Lake quadrangle is underlain by metamorphosed pre-Silurian eugeosynclinal rocks, metamorphosed Silurian and Devonian rocks that are in part fossiliferous, and at least four types of intrusive rocks, according to E. L. Boudette and D. S. Harwood. Fossils, minor sedimentary structures, and pillow structure provide keys to the structural and stratigraphic relations. The pre-Silurian rocks can be differentiated into at least 5 lithologic units, and the Silurian and Devonian rocks into at least 4. Mafic and intermediate intrusive rocks form two relatively large plutons. Several serpentine bodies are associated with greenstone and closely related rocks. Disseminated copper sulfides have been identified in the field in metagraywacke in the contact aureole of a quartz diorite body.

In the Rangeley quadrangle in Franklin County, western Maine, according to R. H. Moench, Silurian(?) strata of conglomeratic to pelitic composition, possibly more than 20,000 feet thick, are overlain to the southeast by an unknown thickness of Devonian(?) strata of dominantly pelitic composition. The so-called Rangeley Conglomerate of Smith, 1923, the lowest unit in this section, grades southeastward to sandstone. This and other possible facies changes suggest that abundant sediments were derived from the Border Mountains anticlinorium, a short distance to the northwest. Tight folding along northeast-trending axes probably in part accompanied sedimentation, as some rocks show evidence of being deformed before consolidation.

The major structural feature in the Stratton quadrangle in the upper Kennebec River basin, mapped by Andrew Griscom, is an east-trending anticline along whose axis pre-Silurian(?) sandstone and sulfide-bearing shale are exposed. Above those rocks are a limy quartzite of Silurian age and a rhythmically bedded siltstone of Devonian(?) age. The sedimentary rocks are extensively intruded and metamorphosed by Devonian plutons of quartz monzonite, diorite, and layered norite and gabbro.

A zone of lenticular iron-bearing manganese deposits that strikes into hornfels around felsic plutons in the Smyrna Mills quadrangle, Aroostook County, has been traced across the Houlton quadrangle by Louis Pavlides. Local magnetic highs associated with the hornfels aureoles probably are caused by magnetite formed by thermal metamorphism of the iron-bearing manganese deposits.

Stream-sediment sampling by Louis Pavlides and F. C. Canney, in a terrane of folded Paleozoic rocks and felsic plutons in the Smyrna Mills quadrangle, reveals a weak zinc anomaly in 1 stream draining hornfels and a higher-than-background molybdenum content in 4 streams that drain an area underlain by felsic rocks and hornfels. Variations in copper and molybdenum content with time at several localities are inversely related to variations of stream discharge.

F. C. Frischknecht and P. E. Pennell have found that highly metamorphosed sulfide-bearing rocks in the Phillips and Rangeley quadrangles in Franklin County are good electromagnetic conductors. Although these rocks contain some carbon, their conductivity seems to be determined primarily by the sulfides, which occur in thin continuous sheets. Metamorphism is of lower grade in most other areas in northern Maine; consequently, sulfide minerals are disseminated and have only a minor influence on conductivity of the rocks.

The regional northeast strike of geology in Maine is reflected by four major belts of magnetic anomalies that range in trend from N. 40° E. in the west to N. 65° E. along the coast, according to M. F. Kane. The anomalies indicate the presence of two major belts of igneous rocks, one along the coast and the other in the north-central part of the State. One belt of sedimentary rocks lies between the igneous belts, and another occupies the northwest part of the State. The coastal igneous belt consists of an inner zone of felsic, apparently stratiform plutons, and an outer zone of mafic rocks. The close parallelism of the two zones with the coastline suggests that the position of the coast here is controlled by the presence of the igneous rocks.

#### Geophysical studies in New Hampshire

Very consistent directions of remanent magnetization, both normal and reversed, have been observed by Andrew Griscom in the White Mountain Plutonic-Volcanic Series and similar intrusions in New Hampshire and adjacent Maine.

#### Geologic and geophysical studies in Massachusetts

A small diapiric dome has been mapped by P. H. Osberg in the central part of the Plainfield quadrangle, in northwestern Massachusetts. The core of the dome consists of coarse feldspar-quartz-biotite gneiss similar to the Bethlehem Gneiss of New Hampshire. The gneiss has crosscutting relations to the surrounding metasedimentary rocks, and at some places contains ghostlike inclusions of amphibolite. The gneissic core and adjacent metasedimentary rocks have a cleavage that is nearly horizontal near the center of the dome and dipping steeply outward toward the margins. The cleavage is folded by "reverse" drags, as is the bedding in the adjacent rocks. Minor structures consistent with the Green Mountain–Berkshire anticlinorium are superimposed on the structures of the dome.

A. H. Chidester has mapped the bedrock geology of the Rowe quadrangle, just north of the Plainfield quadrange along the Vermont border, using stratigraphic units recognized in Vermont. The rocks show two stages and styles of folding. Several talc bodies found in the quadrangle are possibly of future economic value.

A principal objective of E-an Zen's continuing study of the Taconic sequence of western Massachusetts and adjacent Connecticut and New York is to determine the relations of the sequence to the underlying early Paleozoic Stockbridge Limestone. The Stockbridge has been divided into 8 units, closely comparable with formations in Vermont; the lower 3 units are dolomitic and the next 4 are more calcitic. The top unit is a thin-bedded dark-gray limestone that contains Middle Ordovician fossils at a locality in the Pittsfield West quadrangle and grades upward into black schist, part of Dale's Berkshire Schist. The Stockbridge grades downward into the basal Paleozoic Cheshire Quartzite. This stratigraphy provides a basis for mapping the internal structure of the Stockbridge; preliminary results indicate the presence of large flat-lying folds and thrust faults as well as later, more readily recognizable high-angle faults. Mineral assemblages in the carbonate rocks and the overlying schists show that the metamorphic grade rises rapidly southeastward near the Massachusetts–Connecticut line, from chlorite zone to staurolite zone in about 15 miles. One of the major difficulties in the study of the Taconic rocks is the profusion of stratigraphic names, and therefore a comprehensive review of the definitions and synonymies of these names has been made.

Excellently preserved fossils have been found by N. P. Cuppels in glacial boulders in the Georgetown quadrangle, north of Salem in northwestern Massachusetts. The fossiliferous boulders are of light-gray to light-green siltstone similar to that in outcrops of the Newbury Formation less than a mile north of the kame in which the boulders occur. The fossils have been identified by A. J. Boucot as a fauna equivalent to that of the Silurian Pembroke Formation of eastern Maine.

The oldest rocks exposed in the Blue Hills quadrangle south of Boston, mapped by N. E. Chute, are metamorphosed sediments and basic volcanic rocks that resemble the Marlboro Formation of Precambrian(?) age. These are intruded by Salem Gabbro-Diorite, Newburyport Quartz Diorite, Dedham Granodiorite, and a granite. In the northern part of the quadrangle, felsitic volcanic rocks similar to the Mattapan Volcanic Complex are intruded by the Blue Hill Granite Porphyry. The porphyry long known as rhombenporphyry grades into Sharon Syenite, but is intruded by both the Blue Hill Granite Porphyry and the Quincy Granite. These relations, together with data from the Norwood quadrangle just to the west, fix the age of the Sharon Syenite as younger than the Salem Gabbro-Diorite and older than the Blue Hill Granite Porphyry and Quincy Granite.

Surficial deposits in the lower Merrimack valley, mapped by J. E. Cotton, include glaciofluvial deposits at altitudes between 90 and 130 feet. The relations of these deposits to nearby marine clay at an altitude of 80 feet, and to marine clay interstratified with sand and gravel at lower altitudes, are expected to provide important clues in interpreting the history of glaciofluvial and marine deposition following the retreat of the last ice sheet.

Evidence for two glacial lakes, Lake Sudbury and Lake Concord, has been recognized by Carl Koteff near Concord (Art. 96). Lake Sudbury, first outlined by J. W. Goldthwait in 1905, had several outlets, but only the Cherry Brook outlet affected the history of the lake in the Concord quadrangle. Deltas built from the ice front immediately south of Concord enclosed Lake Sudbury on the north, and further retreat of the ice formed Lake Concord north of these deltas. Lake Concord had two major stages, both controlled by outlets to the east in Lexington; the high stage is represented by deltas such as Revolutionary Ridge in Concord, and the low stage by deltas about 40–45 feet lower. The lake was drained when the retreating ice uncovered the Shawsheen valley. Postglacial tilt of the area was probably between 5 and 6 feet per mile.

Glauconite has been found by N. E. Chute in all the glacial and beach deposits in the Scituate and Duxbury quadrangles south of the village of Scituate. A reconnaissance of southeastern Massachusetts shows that a small amount of glauconite is present in the glacial and beach deposits in eastern Plymouth County and on Cape Cod. Unconsolidated glauconitic sand and fine gravel, overridden and partly eroded by the last ice sheet, were the source of the glauconite. These deposits underlie the Marshfield Hills in the Scituate and Duxbury quadrangles and probably underlie much of Cape Cod Bay. They appear to be remnants of coastal plain sediments that may range in age from Cretaceous to Pleistocene.

According to R. W. Bromery, aeromagnetic and ground magnetic data in the Greenfield area indicate that some of the Triassic basalt flows have directions of remanent magnetism different from those of other Triassic igneous rocks. Aeromagnetic and gravity data in the area of the Colrain dome indicate that the central part of the dome consists of a core of less dense, weakly magnetic rocks covered by more dense, more strongly magnetic rocks. Magnetic and gravity data in eastern Massachusetts and Cape Cod suggest the presence of a large linear mafic rock mass, generally parallel to the coast, and perhaps correlative with a similar occurrence reported from coastal Maine by M. F. Kane.

### Geologic mapping in Rhode Island

G. E. Moore, Jr., has found that the Ponaganset Quartz Diorite Gneiss in the Clayville quadrangle, west of Providence, contains diversely oriented inclusions of metasedimentary gneiss, and appears to have been intruded as a magma. It shows primary flow structure and two secondary cleavages, one pervasive and one restricted to shear zones.

A fine-grained, well-foliated biotite granite gneiss in the Ashaway quadrangle, in southwestern Rhode Island and Connecticut, formerly included in the Sterling Granite Gneiss of Emerson, is now recognized by T. Feininger as a distinct unit. This gneiss is believed to be a syntectonic magmatic rock, associated with Devonian(?) instrusive rocks to the east. The geologic map indicates that the gneiss was forcibly intruded into older metamorphic rocks. Several outcrops expose a layer, believed to be a screen, that contains quartz-sillimanite nodules as much as 6 inches long.

### Geologic mapping in Connecticut

A major thrust fault striking northward has been mapped by H. R. Dixon in the Plainfield and Danielson quadrangles in eastern Connecticut, separating the rocks of the lower part of the Putnam Gneiss from the underlying Sterling Granite Gneiss and Plainfield Quartzite of Perhac, 1958. The fault is characterized by dense mylonites and cataclastic augen gneisses, and cataclastic effects can be seen in a zone about half a mile wide on either side of the fault. Secondary, probably late effects in the fault zone include brecciation, loose fracturing, and quartz veining. The fault is possibly the northward extension of the Honey Hill fault of southern Connecticut, mapped by Goldsmith, Lundgren, and Snyder.

As a result of mapping in eastern Connecticut, H. R. Dixon has given group status to the Putnam Gneiss, and divided it into two formations. A formation of primary metasedimentary rocks overlies a formation of primarily metavolcanic rocks.

The Lebanon Granite covers more than four times the area formerly mapped, according to G. L. Snyder. Rather than being restricted to the Willimantic quadrangle in eastern Connecticut as previously thought, it extends south and east into the adjoining Colchester, Columbia, and Fitchville quadrangles. In the Willimantic quadrangle the plagioclase of the intrusive varies zonally from 30 percent anorthite near the southern margin of the quadrangle to 90 percent anorthite near the northern margin. Mappable central zones are richer in mafic minerals than the rocks away from the center.

Scintillometer traverses by H. E. Simpson in the New Britain quadrangle in central Connecticut have been found very useful in tracing faults. Especially in the east half of the quadrangle, glacial drift effectively conceals all significant faults. The scintillometer traverses reveal points of higher radioactivity that may be attributed to undetermined radioactive materials carried upward by ground water along the faults.

Twin recessional moraines of the Wisconsin Glaciation have been mapped by Richard Goldsmith across the Niantic quadrangle in southeastern Connecticut. These moraines are a quarter to half mile apart and are mostly between 200 and 300 feet wide. Patches of ablation till to the northeast in the Uncasville and New London quadrangles appear to be alined with these moraines. The Niantic moraines lie about 4 miles south of the similar Ledyard moraine,[45] and about 8 miles north of the line of the Harbor Hill moraine of Long Island.

### Geologic mapping in eastern New York

C. S. Denny has found that the Ingraham esker in the Rouses Point quadrangle near Chazy has a core of glacial drift overlain by fossiliferous deposits of the Champlain sea. The presence of deformed and oxidized lake silt between drift and marine beds indicates that the esker was submerged under lake waters and then emerged for a brief interval prior to the incursion of the late Pleistocene Champlain sea.

## APPALACHIAN REGION

### Geologic mapping

Mapping by D. L. Southwick has indicated that the "gabbro" north and west of Aberdeen, Md., is a complex of mafic rocks resulting from metamorphism of a gabbro body containing roof pendants of older dacitic or andesitic metavolcanic rocks.

D. W. Rankin has found that rocks of the Mount Rogers Volanic Group of southwestern Virginia extend much farther south into Ashe County, N.C., than was previously recognized. In this southern area, volcanic rocks are interbedded with sedimentary rocks that resemble the Grandfather Mountain Formation. This

[45] Goldsmith, Richard, 1960, A post-Harbor Hill–Charlestown moraine in southeastern Connecticut: Am. Jour. Sci., v. 258, p. 740–743.

mapping has also revealed the presence of magnetite-bearing basalt in western Grayson County, Va., where an aeromagnetic map recently published by the Virginia Division of Mineral Resources shows a large magnetic anomaly.

In Wise and Lee Counties, southwestern Virginia, detailed mapping by R. L. Miller and J. B. Roen demonstrated that the supposed major Pigeon Creek fault of previous geologic maps is a sharp, right-angled flexure without displacement along most of an 11-mile exposure of the structure. Minor displacement of rocks near the flexure was observed at only one locality. A key unit, the Gladeville Sandstone, was traced across the flexure, resulting in revised correlations within the post-Lee Pennsylvanian sedimentary rocks in the area.

Geologic mapping in the Slate Belt of the North Carolina piedmont is continuing. In the Durham area, G. L. Bain has demonstrated the presence of a metavolcanic sequence overlain by interbedded argillite, graywacke, and conglomerate, overlain by tuffs and tuffaceous sediments and intruded by younger plutonic masses ranging in composition from granite to gabbro.

Farther south in the Slate Belt, H. W. Sundelius (Art. 12) found accretionary lapilli in the pyroclastic siltstone, the first such occurrence reported from the eastern United States, which suggests subaerial deposition for these rocks.

In the Uwharrie Mountains of central North Carolina, A. A. Stromquist discovered fossils that were determined by J. M. Schopf to be coalified algae, in a laminated argillite of the Slate Belt. Their age cannot be determined, but they are early Paleozoic, possibly Ordovician.

Mapping related to hydrogeologic studies in Clay County, N.C., indicated that hornblende gneisses in that area are of two varieties, one of which is intrusive into the other.

### Structural and tectonic studies

In Sussex County, N.J., and adjacent counties of New York, Julian Soren has determined that repetition of Silurian and Devonian formations on Shawangunk Mountain and in the Port Jervis trough may be due to northwest-dipping thrust faults. The contact between the Ordovician and Silurian rocks in this area may be a fault, and the outliers of Silurian and Devonian rocks in the Green Pond syncline and Becraft Mountain may be remnants of a large-scale eastward overthrust.

H. H. Arndt and G. H. Wood, Jr., have mapped one of the most intensively faulted areas in the Pennsylvania anthracite region, south of the Broad Mountain anticlinorium. They conclude that the faulting may represent a late east-to-west compressive phase of the Appalachian Revolution which was superimposed on an earlier southeast-to-northwest phase.

Facies differences of Devonian rocks in the Southern Anthracite field lead G. H. Wood, Jr., T. M. Kehn, and J. P. Trexler to conclude that movement on the Sweet Arrow fault is at least 3 to 4 miles, and may be as much as 10 miles or more. Farther east, in the Stroudsburg and Saylorsburg quadrangles, Pennsylvania, A. A. Drake, Jr., and J. B. Epstein interpret the juxtaposition of a carbonate and a quartzose facies of Devonian rocks to be the result of a major fault that lies on the projected trend of the Sweet Arrow fault.

From detailed stratigraphic measurements of the Rome and Conasauga Formations of Claiborne and Hancock Counties, Tenn., L. D. Harris concludes that the Clinchport fault overrides the Hunter Valley fault instead of merging with it, as was previously interpreted. The Clinchport fault also appears to override the Wallen Valley fault, farther to the southwest, and thus must be considered one of the major overthrusts of the region.

### Stratigraphic studies

C. L. Dodson (1–63) has found that, in southwestern North Carolina, the contact between the Great Smoky Group (Precambrian) and the rocks of the Murphy marble belt is gradational, and that lithologies commonly interfinger.

Fossils collected from the Murray Shale of Early Cambrian age on Chilhowee Mountain, Blount County, Tenn., by R. A. Laurence (1–63), have been identified by A. R. Palmer as ostracodes, *Indiana tennesseensis*. This confirms the existence of a long-lost locality originally discovered in 1889 by C. D. Walcott.

### Geophysical studies

An aeroradioactivity survey of an 8,000-square-mile area near Washington, D.C., including parts of the Atlantic Coastal Plain, Piedmont, Blue Ridge, and Valley and Ridge physiographic provinces, shows a close correlation between radioactivity and areal geology. Radioactivity units for each province have characteristic values and have a linear pattern parallel to the north-northeast geologic grain of the region. Radioactivity levels of the Atlantic Coastal Plain are generally low, except in areas of glauconitic beds, or near the inner edge where detrital materials from the Piedmont are present. In the Piedmont and Blue Ridge, radioactivity is lowest over quartzose sedimentary rocks and highest over areas of granite and gneiss. In the Valley and Ridge provinces, it is highest over shale areas and lowest over the carbonate rocks.

A 700-square-mile aeromagnetic survey centered on Harford County, Md., was completed in cooperation with the State of Maryland. The work is in support of geologic mapping being done by D. L. Southwick. Twenty-six new Geophysical Investigations aeromagnetic maps have recently been published for the Piedmont province, fourteen of which (GP 337–350) extend magnetic coverage in the highlands of New York and New Jersey. Four maps (GP 386–389) are for areas in northwestern Virginia, and six (GP 394–399) cover areas mostly in Maryland, near Washington, D.C.

J. S. Watkins concludes from the absence of recognizable gravity and magnetic anomalies in the areas projected downdip from outcropping thrust faults in the Valley and Ridge province of east Tennessee, that the faults do not penetrate the basement. They either die out within the sedimentary section or they extend horizontally southeastward beneath the great overthrusts of the Blue Ridge province.

Further work by R. B. Bates and Henry Bell, III, in the Concord area, North Carolina, has modified earlier conclusions from mapping and airborne geophysical work.[46] For example, 4 areas previously mapped as granite, undivided, contain 2 distinctly different types of rocks, one of which is represented by high radioactivity levels and closed magnetic lows. High-amplitude magnetic anomalies are centered over the contact of gabbro with syenite bodies that form a ring dike. The anomalies suggest concentrations of magnetite within the gabbro at the contact. Similar anomalies which wrap around the southern end of the western syenite body indicate that the gabbro may extend farther along the western side of the syenite than has been recognized in the field.

## EASTERN PLATEAUS

### Geologic studies in western New York

Continued stratigraphic studies of Upper Devonian rocks have enabled Wallace de Witt, Jr., to trace several key black shale members of the West Falls and Sonyea Formations eastward to the vicinity of Elmira, N.Y., where the black shale grades into other types of rock, thus delineating the eastward limit of deposition of black shale in the two formations. During the course of this work, conodonts were found in the Rhinestreet Shale Member of the West Falls Formation about 7 miles north of Elmira, the easternmost known occurrence of conodonts in this member.

[46] Bell, Henry, III, 1960, A synthesis of geologic work in the Concord area, North Carolina: Art. 84 *in* U.S. Geol. Survey Prof. Paper 424–B, p. B189–B191.

Johnson, R. W., and Bates, R. G., 1960, Aeromagnetic and aeroradioactivity survey of the Concord quadrangle, North Carolina: Art. 85 *in* U.S. Geol. Survey Prof. Paper 424–B, p. B192–B195.

### Geologic studies in Pennsylvania

A key conglomerate bed has been used by G. W. Colton in the Cedar Run quadrangle, Tioga and Lycoming Counties, north-central Pennsylvania, to delineate the surface structure and to show the stratigraphic relation between rocks of Late Devonian and Early Mississippian age. Comparison of many measured sections suggests that this thin conglomerate is for the most part continuous over a minimum area of 580 square miles in parts of Cameron, Clinton, Elk, Potter, and Tioga Counties. The full extent of the conglomerate has not been determined. The Pennsylvania Geologic and Topographic Survey has assigned a Mississippian age to this bed, but a fragmentary suite of marine fossils suggests a Devonian age. The top of this easily traced bed has been used to mark the Devonian–Mississippian boundary in the Cedar Run quadrangle.

Coal balls from the Middle Kittanning coal bed, Beaver County, the easternmost known locality in the United States, have been described by J. M. Schopf. These coal balls are calcareous and contain abundant well-preserved fossil plant material, including *Lycopsid periderm*, stigmarian axes and roots, fern sporangia, and sigillarian megaspores. Calcareous coal balls are known only from coal beds that directly underlie rocks of marine origin, and are of possible value in correlating coal beds from one region to another. The most prolific source of calcareous coal balls in the Eastern Interior region is the Herrin (No. 6) coal, which Wanless,[47] using other criteria, has tentatively correlated with the Middle Kittanning coal bed of the Appalachian region.

In Washington County, Pa., H. L. Berryhill, Jr., has shown that the upper limestone member of the Washington Formation (Lower Permian) consists of two limestone sequences separated by siltstone and sandstone both to the south and to the west of the type area at Washington, where the member is a single sequence of limestone beds 30 feet thick. The siltstone-sandstone wedge between the two limestone sequences thickens to the south and to the west. The bifurcation of the upper limestone member away from the type area is of regional stratigraphic significance, for the "Upper Washington Limestone" of Ohio, thought by previous workers to be a correlative of the "Upper Washington Limestone" of Pennsylvania, is probably the lower tongue of the upper limestone member; and the "Jollytown Limestone" of Greene and Washington Counties, Pa., thought by previous workers to be a separate stratigraphic unit, is the lower tongue of the upper limestone member.

[47] Wanless, H. R., 1957, Geology and mineral resources of the Beardstown, Glasford, Havana, and Vermont quadrangles: Illinois Geol. Survey Bull. 82, p. 111.

### Geologic studies in Kentucky

A major undertaking to provide complete detailed geologic map coverage for the State of Kentucky was begun in the fall of 1960, in cooperation with the Kentucky Geological Survey. The maps are being published as 7½-minute quadrangles (scale 1:24,000) in the Geologic Quadrangle Map series. As of June 30, 1963, 40 quadrangles have been published, 78 are in press, 53 are completed and in review, and 85 are currently being mapped. Quadrangles published during fiscal year 1963 are given in the List of Publications (see Kentucky, geologic maps, in the Index to Publications, p. A241).

In southeastern Kentucky, geologic mapping by K. J. Englund and J. B. Roen (3–63) has shown that the Middlesboro basin, about 4 miles in diameter, is underlain by intensely deformed Pennsylvanian rocks that are faulted and folded concentrically around an uplifted core. Deformation is most intense at the center of the basin where previously unrecognized rocks of the basal Pennsylvanian Lee Formation have been uplifted about 900 feet. Quartz grains and pebbles in these rocks are highly shattered. Development of this structure is interpreted as resulting from meteor impact.

Continued studies by K. J. Englund and A. O. Delaney of the stratigraphic relations of the Upper Mississippian Pennington Formation and the lower Pennsylvanian Lee Formation show that the two intertongue in the Jellico area of Kentucky and Tennessee. The area of intertonguing, previously recognized in the Cumberland Mountain area, is thus extended to the Pine Mountain outcrop belt.

Gypsum and anhydrite were penetrated in the lower part of the St. Louis Limestone by two core holes drilled along the east flank of the Western Kentucky coal basin. Bedded evaporites, except in small amounts, are not known to crop out in western Kentucky, although gypsum is mined extensively in Indiana at depths greater than 350 feet. The concentration of gypsum and anhydrite is 35 percent in the interval from 336 to 390 feet in the well east of Guston in Meade County, and 28 percent in the interval from 460 to 509 feet in the well southeast of Summit in Hardin County. The evaporites are in beds 1 foot or more thick, and the estimated ratio of gypsum to anhydrite is 5 to 1.

### Geologic studies in Tennessee

Continued geologic mapping in the southwestern part of the Highland Rim Plateau by M. V. Marcher has shown that the Fort Payne Chert consists of a lower siltstone facies and an upper chert facies. Although the Fort Payne maintains a fairly uniform thickness of about 250 feet, the individual facies thicken and thin abruptly and without apparent pattern. In Wayne and Lawrence Counties the lower part of the Fort Payne locally contains as much as 100 feet of coarse-grained silty cherty crinoidal limestone. Farther north, in Hickman County, similar limestone is near the top of the formation; still farther north, in Dickinson County, limestone is near both the top and base of the formation. Locally these limestones are quarried for use in agriculture and construction. Solution channels along bedding planes commonly feed small springs and, at a few localities, have been tapped by water wells.

### Quaternary geology of the Ohio River valley

New evidence obtained by C. W. Carlston (1–62) on the bedrock longitudinal profile and bedrock width of the upper Ohio River valley suports the theory that the uppermost part of the Ohio River once flowed northward and was later diverted to its present course and direction of flow. From Pittsburgh Pa., to mile 114 below Pittsburgh the width of the Ohio River valley progressively decreases, while below mile 114 the valley width progressively increases. The bedrock profile shows a well-defined prominence at mile 114. These features suggest that mile 114 was the location of a divide that separated north- and south-flowing drainage systems. The Illinoian glacial advance into northwestern Pennsylvanian dammed the north-flowing drainage, and diverted it to its present course southward along the Ohio River valley. The valley was deepened and broadened during the Sangamon Interglaciation and was filled with fluvioglacial deposits during Wisconsin Glaciation. These deposits are the sources of large quantities of ground water that are used extensively by industries along the Ohio River valley.

Continued geomorphologic studies of the lower Ohio River valley by L. L. Ray have yielded new data about the various stages of Quaternary alluviation. The sequence of events controlling the alluviation of the unglaciated lower Ohio River valley during the several glacial and interglacial stages is summarized in Article 33.

Reconnaissance studies by L. L. Ray at the well-known vertebrate fossil locality of Big Bone Lick, Ky., adjacent to the Ohio River valley, indicate 3 periods of valley alluviation now represented by remnants of 3 terrace levels above the present flood plain of Big Bone Creek. The oldest and highest terrace is of Wisconsin (Tazewell) age, some 18,000–19,000 years ago. Preliminary work suggests that each of the three terraces may contain a distinctive vertebrate fauna.

As a result of studies of weathering profiles in loess deposits of the lower Ohio River valley, L. L. Ray (1–63) has found that silt-clay ratios for each zone within the Peorian Loess are uniform over the region, and are distinct from those of the underlying Farmdale Loess, thus providing a basis for regional correlation and for evaluating the postdepositional history of the deposits.

## SHIELD AREA AND UPPER MISSISSIPPI VALLEY

### Geologic and geophysical studies in Iowa

Lower Silurian rocks disconformably overlie and are lithologically similar to Maquoketa Shale of Late Ordovician age in and near Dubuque County, Iowa. J. W. Whitlow and C. E. Brown (Art. 62) report that this transitional contact can be recognized by a thin persistent basal conglomerate in the Silurian rocks and, locally, by rare erosional remnants of the iron-rich Neda Member of the Maquoketa Shale.

J. R. Henderson, W. S. White, and Isidore Zietz (3–63) have completed a preliminary geologic interpretation of the northern part of a 15,000-square-mile central Iowa aeromagnetic survey. Principal features on the aeromagnetic map were used to prepare a provisional geologic map showing the distribution of Precambrian rocks beneath a Paleozoic cover. The authors' findings are in general agreement with results from other geophysical investigations in Minnesota, Wisconsin, and Michigan along the "midcontinent gravity anomaly" which extends for 800 miles southwest from Lake Superior. The gravity high correlates with an intense magnetic high. Both features are apparently caused by a geosyncline filled with a section of lavas of Keweenawan age several miles thick, similar to the copper-bearing lavas found farther north, on the Keweenaw Peninsula of Michigan. The lava belt, which is about 15 miles wide at the Iowa–Minnesota border, becomes progressively wider farther south. At the latitude of Fort Dodge, Iowa, the belt is about 50 miles wide. Locally deep troughs of younger sandstones flank the lavas. The shallow core of the disturbed area at Manson, believed by some writers to be a cryptovolcano, is shown to be larger than previously reported.

### Geologic and geophysical studies in Minnesota

Surficial geology of a 4,400-square-mile area in Minnesota that includes the Mesabi and Vermilion iron ranges has been mapped by R. D. Cotter, H. L. Young, and T. C. Winter. The distribution of four tills of late Wisconsin age, of their associated stratified drift, and of unclassified discontinuous glacial debris over bedrock is outlined. End moraines, outwash plains, ice-contact areas, drumlinoid ridges, and altitudes and boundaries of glacial lakes are shown. Studies of open-pit exposures and test-hole logs have led to the tentative correlation of the four tills, and also of an older till in the subsurface.

The relation of magnetic anomalies in northern Minnesota to known geologic sources has been studied by G. D. Bath. He divides the anomaly-producing rocks into three main groups that provide for limiting possible sources of the anomalies in drift-covered areas where geologic interpretation must be inferred from a few widely spaced water wells. In northeastern Minnesota, strongly magnetized rocks with dominant remanent magnetization are iron-formations of early and middle Precambrian age, and diabase, basalt, and gabbro of Keweenawan age; moderately magnetized rocks with dominant induced magnetization are igneous intrusives of intermediate composition; and weakly magnetized rocks are batholiths of granitic composition that are of pre-Keweenawan age. Iron-formations of early Precambrian age appear to be the source of many of the strong anomalies found in the north-central and northwestern parts of the State.

### Geologic and geophysical studies in Michigan

Several westward-trending faults between Palmer and the eastern part of Negaunee, Mich., have been found by J. E. Gair. The faults are indicated mainly by displacements of the contacts between the Siamo Slate and an extensive metadiabase sill, between the Siamo Slate and the Negaunee Iron-Formation, and between the Ajibik Quartzite and the Wewe Slate.

A magnetic map based on an aeromagnetic survey of part of Marquette County, Mich., is interpreted by J. E. Case and J. E. Gair as characterized by four main types of anomalies. Prominent relatively continuous anomalies of as much as 20,000 gammas are caused by iron-bearing formations which are magnetic. Discontinuous anomalies of as much as 5,000 gammas are caused by serpentinized peridotites and mafic intrusives. Prominent westward-trending anomalies of low values are over negatively polarized diabase dikes of Keweenawan age. Discontinuous anomalies of high and low values of small range are characteristic of areas underlain by a complex of granitoid gneiss, volcanic greenstone, serpentinized peridotite, and metagabbro or metadiabase. The magnetic map and an interpretation of the map, especially in reference to known and inferred iron-formations, are in preparation for publication.

### Geologic studies in Wisconsin

In geologic investigations in the Florence area, Wisconsin, C. E. Dutton found that in the southern part of the area, metabasalt of early Precambrian age and sill-like masses of metagabbro of late middle Precambrian age are in an andesine-amphibolite facies of metamorphism. The distribution of differences in composition of plagioclases suggests a probable aureole relation to a younger granite. An oligoclase-amphibolite facies of westerly trend in the adjacent area to the east does not extend into the project area but turns northward and is truncated by a major northwestward-trending fault at the north limit of the metabasalt and associated metafelsic volcanic rock.

## INTERIOR HIGHLANDS AND EASTERN PLAINS

The Crooked Creek and Decaturville, Mo., crypto-explosion structures show a complete development of geology and mineral deposits in several stages. They are alined on major faults or at the intersections of major regional structures, and they have shattercones pointing in many directions. Thor Kiilsgaard, M. R. Brock, and A. V. Heyl (1–63) have found that these relations are incompatible with a simple-impact hypothesis. Other circular structures show none of these features and may be impact structures.

In the Lesterville quadrangle of southeast Missouri, Thor Kiilsgaard finds that the transgressive facies of "White dolomite," reported by him in 1962, is more extensive than had previously been believed. This facies is related to the Precambrian subsurface and covers large areas in the region south of the St. Francis Mountains. The facies extends from the Bonneterre Dolomite into the Eminence Dolomite, both of Late Cambrian age, and is extensive both laterally and vertically.

Mapping in the Bakers Crossing quadrangle, Texas, by Val L. Freeman has provided detailed information on the structure of two en-echelon areas, each trending east-west and each about a mile wide and 4 miles long, where solution of limestone at depth has caused subsidence at the surface. Subsidence of the surface rocks has been accomplished both by faulting and downwarping. Solution of the underlying limestones was probably localized along zones of joints that may represent an incipient fault. No through-going fault is present, although the zones are alined with a fault that is several miles to the east.

## NORTHERN ROCKY MOUNTAINS AND PLAINS

### Geologic studies in northeastern Washington

Tertiary volcanic and sedimentary rocks that occur in a large graben in the Republic and Aeneas quadrangles, Ferry County, Wash., have been subdivided by Siegfried Muessig (1–62) into four new formations: the tuffaceous O'Brien Creek Formation of Eocene(?) age, the next younger Eocene(?) San Poil Volcanics. the intrusive Scatter Creek Rhyodacite of Eocene or Oligocene age, and the volcanic Klondike Mountain Formation of Oligocene age.

North of the Aeneas quadrangle, in the Bodie Mountain quadrangle, R. C. Pearson has found deposits of coarse breccia in the lower part of the Klondike Mountain Formation. These deposits contain discrete blocks as much as several thousand feet long that are similar in lithology, and probably in mode of emplacement, to slabs as much as 2 miles long that lie a short distance to the east. Both the breccia deposits and the large slabs probably were derived from the east side of the Republic graben, about 10 miles east of their present position, by dislodgment during movement along the bounding graben fault.

The structural trends of older metamorphic and igneous rocks in the Spokane area are in a north-northeast direction, but those in the Columbia River Basalt are west-northwest, according to A. B. Griggs. A northwest-trending zone of quartz latite dikes, probably equivalent to the Gerome Andesite of Oligocene age, cuts the older metamorphic and igneous rocks in the Wilmont Creek quadrangle northwest of Spokane, according to George E. Becraft. The zone may represent a northward extension of the Spokane River valley–Enterprise valley fault system of the Turtle Lake quadrangle. If this is the case, it is the first known northwest-trending structure of such magnitude in this area.

### Geologic studies in northern Idaho and western Montana

Facies studies and new correlations of Belt rocks between Clark Fork, Idaho, and Superior, Mont., indicate that the trough of deposition shifted significantly at the beginning of Missoula Group (Belt Series) time. J.E. Harrison and A. B. Campbell report that the trend of the trough of deposition of pre-Missoula Group rocks was northwest, through Missoula and Libby, Mont., whereas the trend of the Missoula Group trough was northeast, about at right angles to the older trough, and was centered near Missoula. Overlap and removal of rock-stratigraphic units toward Clark Fork, Idaho, suggest that the source area for at least part of the Missoula Group was to the northwest of Clark Fork.

The Flathead(?) Sandstone of Middle Cambrian age rests unconformably on the Belt rocks of Precambrian age over a wide area in the western part of the Lewis and Clark Range, near the headwaters of the Sun River, Montana. According to M. R. Mudge the amount of erosion of Precambrian rocks prior to Cambrian deposition differed considerably from place to place. The thickest stratigraphic section of Belt rocks in this area is exposed in the southwestern corner of the Pretty Prairie quadrangle in northwestern Lewis and Clark County. About 7 miles farther south, the Flathead(?) Sandstone rests on Belt that is about 3,000 feet lower stratigraphically. To the north, however, the unconformity cuts no lower than 300 feet stratigraphically below the top of the thickest section.

In the Wolf Creek area, Montana, R. G. Schmidt has studied a segment of the Eldorado overthrust that brings rocks of the Belt Series of late Precambrian age northeastward over volcanic rocks of the Two Medicine

Formation of Late Cretaceous age. Although the evidence is not entirely conclusive, it appears that major faults in this area developed first in the east and then progressively farther west, culminating in movement along the Eldorado overthrust.

In the Highland Mountains, south of Butte, M. R. Klepper and H. W. Smedes have mapped a thick east-trending sequence of thermally metamorphosed Belt strata. Five stratigraphic units have been mapped; each has maximum thickness in the central part of the mountains and rather abruptly wedges out or thins to the east and west. Three of the units also show marked changes in facies to the east and west. The greatest aggregate thickness is about 15,000 feet.

A major structural lineament trending N. 25° E. was recognized by H. W. Smedes in the Butte North quadrangle, northwest of Butte. It appears to be a zone of faulting which controlled emplacement of part of the Boulder batholith in Late Cretaceous or early Tertiary time, and which was rejuvenated during the deposition of the Lowland Creek Volcanics in late Oligocene time, and again during Quaternary time. The great importance of faults in localizing the emplacement of the batholith was further demonstrated by M. R. Klepper and R. I. Tilling. They have shown that in the Twin Bridges quadrangle many of the contacts between different plutons of the batholith and between batholithic and older rocks follow major prebatholithic faults of northwest, north, and northeast trend.

Tertiary rocks in the Anaconda 3 NW quadrangle can be divided into a volcanic sequence of Oligocene age correlated with the Lowland Creek Volcanics, an overlying conglomerate of probable Miocene age, and onlapping gravel deposits of Pliocene age, according to A. A. Wanek and C. S. Barclay. The structural relations of these units indicate that the major period of deformation in Late Cretaceous or early Tertiary time was followed by lesser periods of deformation during late Oligocene, Miocene, and Pliocene time.

A rodent jaw found by Laura McGrew in the coarse tuffaceous Tertiary beds of the northeasternmost Three Forks Basin, Montana, has been identified as *Eumys* sp. of Oligocene age by G. E. Lewis. These beds formerly were correlated with the Miocene and Pliocene of the western part of the basin on the basis of lithology.

A study of gravity data in the eastern part of the Three Forks Basin by W. E. Davis and W. T. Kinoshita has revealed bedrock depressions, estimated to be between 5,000 and 6,000 feet deep, along the front of the Gallatin Range and the southern part of the Bridger Range. In Dry Creek valley in the northern part of the basin the bedrock surface is about 3,000 feet deep beneath Cenozoic sedimentary deposits.

The western part of the Crazy Mountains basin in south-central Montana contains more than 13,000 feet of continental deposits of latest Cretaceous and Paleocene age, formerly assigned to the Livingston Formation. In the type area, the lower half of this sequence has been redefined by A. E. Roberts (Art. 22) as the Livingston Group, divided into four new formations, and the upper half now is assigned to the Fort Union Formation.

The completion of field mapping and the reexamination of several selected localities in the Tepee Creek quadrangle in Gallatin County, Mont., by I. J. Witkind, have raised doubts concerning the existence of the two parallel bedding-plane faults that were thought to extend across the area.[48] The Jefferson Dolomite and the Three Forks Formation, which were earlier thought to have been cut out by one of the bedding-plane faults, have been provisionally identified in the area on the basis of fossil collections. Other fossil collections suggest that the Madison Group is about 400 feet thicker than normal over much of the area, but Witkind considers the excessive thickness a local depositional phenomenon rather than the result of bedding-plane faulting, and he suggests that the earlier reported bedding-plane faults probably do not exist in the Tepee Creek quadrangle.

#### Geologic and geophysical studies in central and southeastern Idaho

High-angle faults trending east and north cut the Idaho batholith and old metamorphic rocks near Big Creek, Idaho, and the previously unexplained patches of Casto Volcanics of Permian(?) age have been shown by B. F. Leonard to be preserved in downdropped fault blocks. The largest fault has been mapped for about 10 miles, and has an apparent vertical displacement of perhaps several thousand feet. Faulting seems to be both older and younger than some Tertiary dikes of a large swarm that runs north through the Big Creek quadrangle.

Relics of metavolcanic breccia older than the Casto Volcanics have recently been found by Leonard in Idaho batholith rocks in the southwest corner of the Yellow Pine quadrangle. Thus the northwest-trending folded belt of old metavolcanics described from Big Creek[49] may have been as much as 30 miles wide.

[48] Witkind, I. J., 1962, Possible detachment faults in the Tepee Creek quadrangle, Gallatin County, Montana: Art. 3 *in* U.S. Geol. Survey Prof. Paper 450-B, p. B6-B8.

[49] Leonard, B. F., 1962, Old metavolcanic rocks of the Big Creek area, central Idaho: Art. 5 *in* U.S. Geol. Survey Prof. Paper 450-B, p. B11-B15.

In the northern part of the Leadore quadrangle, the Paleozoic sedimentary rocks and Tertiary(?) granite that here underlie the Beaverhead Range have been cut by at least four sets of faults, according to E. T. Ruppel. The oldest faults yet recognized are flat thrusts. These were later cut by west-trending high-angle faults, and still later both the thrusts and the high-angle faults appear to have been folded. The folded earlier faults have since been cut by range-front faults, and by north-trending faults that may have a major component of lateral movement.

In the valley of the Snake River southeast of Irwin, Idaho, D. A. Jobin and P. E. Soister have mapped northeast-dipping megabreccia interbedded with post middle Pliocene fanglomerate immediately southwest of the northwest-trending Snake River Range. The breccia probably is composed of blocks from the steep fault-line scarp of the Snake River Range. Pearson (p. A82) has suggested a similar origin for the megabreccia in the Bodie Mountain quadrangle in northeastern Washington. The dip of the breccia toward the Snake River Range probably is the result of about 500 feet of displacement on the range-front fault since middle Pliocene time.

According to H. F. Albee and M. H. Staatz, varicolored beds as much as 75 feet thick at the base of the Wells Formation in the Big Hole Mountains have yielded brachiopods that J. T. Dutro, Jr., has identified as similar to some in the Mississippian part of the Big Snowy Group, and the rocks tentatively are assigned a Late Mississippian age. Albee and Staatz suggest that these varicolored beds can be correlated with the lower beds of the Amsden Formation, which is also of Late Mississippian age.

Parts of what may prove to be two eastward-dipping thrust faults have been mapped in fault blocks in the southwest part of the Bancroft quadrangle west of Soda Springs, by S. S. Oriel. The thrusts have stratigraphic throws of 4,000 to 5,000 feet. Oriel also states that in the Portneuf and Fish Creek Ranges, late block movements were mainly along three distinct sets of faults; at least two periods of movement occurred along one set.

Gravity observations delineate two gravity lows in Gem Valley in Caribou County, one at the north end and one at the south end of the valley. According to D. R. Mabey and F. C. Armstrong (1–62), the northern anomaly could be produced by a depression filled with a maximum of 9,000 feet of beds having a density 0.5 g per $cm^3$ less than the enclosing rocks. The high separating the two lows is interpreted as a topographic high on the surface of the Paleozoic rocks underlying the valley. Magnetic highs are interpreted as indicating the position and trend of fault-fissure sources of some of the surface basalt flows.

Regional gravity observations across the overthrust belt in southeastern Idaho and western Wyoming indicate an area of strongly positive free-air anomalies over the overthrust belt. According to D. R. Mabey, the anomalies indicate that the high regional topography of the belt is not completely compensated by a mass deficiency at depth.

**Geologic studies in Wyoming**

Precambrian metasedimentary gneisses in the northern part of the Teton Range were deformed at least twice before emplacement of the youngest pegmatitic and granitic rocks, according to J. C. Reed, Jr. (Art. 60). Isotopic ages determined by Giletti and Gast on similar pegmatite in the southern part of the range suggest that it may be as much as 2,600 million years old. If the pegmatites in the northern part of the range are this old, the metasedimentary gneisses may be among the oldest rocks exposed in North America.

A series of stratigraphic sections 2 to 4 miles apart, in Grand Teton National Park, have such extensive differences in facies and thickness that they must originally have been many miles apart, according to J. D. Love. He suggests that the different facies subsequently were brought together by horizontal movement along the Jackson and Cache thrusts.

In Lincoln County, in southwestern Wyoming, moderately abundant subsurface data in the Fort Hill quadrangle studied by S. S. Oriel indicate that 3 and locally 4 thrust slices compose the thrust sheet above the Darby (?) fault exposed on Hogback Ridge.

A third detachment fault, within the area of the more extensive Heart Mountain fault a few miles east of the northeast border of Yellowstone National Park, has been named the Reef Creek fault by W. G. Pierce. Movement is thought to be caused by a combination of gravitational sliding and a jiggling surface motion imparted by strong earthquake tremors.

Another detachment fault, the Enos Creek detachment thrust, has been mapped by W. L. Rohrer in the Adam Weiss Peak quadrangle in the southwestern part of the Big Horn Basin. This thrust, which is not related to either the South Fork thrust or the Heart Mountain thrust, has moved to the northeast, and remnants of the thrust form a cap on Squaw Teats, about 12 miles north of Grass Creek. The intensity of deformation in the thrust sheet, which is composed entirely of Eocene rocks, decreases toward the source area, and there has been broad tectonic trenching of the underlying rocks. Earthquakes accompanying the extensive volcanism in the Yellowstone–Absaroka volcanic province probably triggered the movement.

In central Wyoming, Laramide crustal movements have been found by W. R. Keefer and J. D. Love to be predominately vertical rather than horizontal. Subsidence of parts of the Wind River Basin was as much as 16,000 feet, and the Granite Mountains were uplifted as much as 20,000 feet.

Compilation of data on the Pennsylvanian stratigraphy of Wyoming has led to recognition by W. W. Mallory (2–63) of an additional major tectonic element of the ancestral Rocky Mountains, a group of uplifts that rose in Colorado and adjacent States during the Pennsylvanian Period. Previously three major uplifts were recognized, the Uncompahgre and Front Range uplifts in Colorado and the Zuni-Defiance uplift in Arizona–New Mexico. The new paleotectonic element, called the Pathfinder uplift, had its greatest extent and most pronounced expression in Atoka (Middle Pennsylvanian) time when it extended from the vicinity of Laramie northward to Casper, and westward to the southeast corner of Fremont County, Wyo. Recognition of this large paleotectonic element allows a detailed interpretation of the geologic history of the surrounding region during much of Pennsylvanian time.

E. K. Maughan (Art. 66) has found evidence of a low land area that had a position similar to that of the ancestral Front Range as early as Early Mississippian time.

An unconformity discovered by E. D. Maughan within the Park City Formation on the northern flank of the Owl Creek Mountains is believed to have formed during a regressive phase that separated two eastward transgressions of the sea in Permian time.

The oldest and highest terrace in the Big Horn Basin, atop Tatman Mountain, formerly was assigned ages ranging from Eocene to Pleistocene, but is now known to be of early Pleistocene age. W. R. Rohrer extrapolated the physiographic age from known upper Pleistocene deposits, and E. B. Leopold confirmed the extrapolated early Pleistocene age by palynological analysis (Art. 71).

Three tills of pre-Wisconsin age were found by G. M. Richmond (2–62) to overlie one another at Bull Lake on the east side of the Wind River Mountains. The three glaciations represented by the tills are named, from oldest to youngest: Cedar Ridge Glaciation, Sacagawea Ridge Glaciation, and Dinwoody Lake Glaciation. They probably are equivalent respectively to the Nebraskan, Kansan, and Illinoian Glaciations of the midcontinent region.

### Stratigraphic studies in eastern Montana, western North Dakota, and north-central South Dakota

Regional stratigraphic studies by C. A. Sandberg indicate that a black and yellowish-brown carbonaceous shale and siltstone sequence of latest Devonian and earliest Mississippian age is widespread in northern Wyoming and south-central Montana. This lithologic unit overlies a regional unconformity that truncates the Three Forks and Jefferson Formations. It was deposited in a narrow northeast-trending basin penecontemporaneously with the Englewood Limestone in the Black Hills area and the upper part of the Bakken Formation in the Williston basin.

The type sections of the Paine and Woodhurst Members of the Lodgepole Formation in the Little Belt Mountains were remeasured by W. J. Sando and J. T. Dutro, Jr., and the faunal zones established elsewhere in the northern Rocky Mountains were recognized. The Mission Canyon Limestone in the Little Belt Mountains was found to be more than twice as thick as previously reported. In addition, a lithostrotionoid coral bed near the top of the Mission Canyon suggests both a correlation with the type Madison at Logan, Mont., and a Meramec age for the uppermost part of the Mission Canyon in the Little Belt Mountains.

A large, diverse Foraminiferal fauna has been found by J. F. Mello in the upper part of the Pierre Shale of north-central South Dakota, mostly in the Mobridge Member. The majority of species of Foraminifera are conspecific with Gulf Coast forms and indicate a correlation of the upper part of the Pierre Shale in this area with beds of Navarro age on the Gulf Coastal Plain.

### Geologic and geophysical studies in the Black Hills

An excellent correlation exists between gravity anomalies and major sedimentary structures along the western side of the Black Hills and eastern margin of the Powder River Basin. Analysis of the gravity data by R. A. Black suggests that the major sedimentary structures such as the Black Hills monocline, Fanny Peak monocline, and Old Woman anticline are the result of faulting in the Precambrian basement rocks.

In the Hill City quadrangle, located in the southern Black Hills, J. C. Ratté has found that the regional structure of the Precambrian rocks was produced by shear deformation.

## SOUTHERN ROCKY MOUNTAINS AND PLAINS

### Geology of Precambrian rocks

Intensive studies in the important Colorado mineral belt area of the central Front Range west of Denver, Colo., were continued during fiscal year 1963 by R. B. Taylor, W. A. Braddock, P. K. Theobald, D. M. Sheridan, and C. T. Wrucke in the Blackhawk, Empire, Berthoud Pass, Squaw Pass, and Boulder quadrangles. The main structures in the Precambrian rocks have resulted from three successive periods of deformation. The oldest deformation developed broad warps and smaller associated folds whose axes trend northwest, and appears to be at least partly syntectonic with the Boulder Creek Granodiorite. The foliation in much of the interior of the main Boulder Creek batholith west of Boulder, Colo., is of igneous origin, whereas the foliation along the northern edge of the body is gneissic and formed during regional metamorphism. During a second period of deformation, north-northeast-trending folds were superimposed on the older folds. The third period of deformation began with folding around east-northeast-trending axes, and progressed into cataclasis along shear zones of this trend. West of Central City, plastic folding during the third period of deformation predated intrusion of the Silver Plume Granite, but the succeeding cataclasis in part postdated the intrusion.

Major shear zones of three principal trends have been mapped by P. K. Theobald in the Berthoud Pass quadrangle near the crest of the Front Range; each underwent movement during both Precambrian and Tertiary times, and each was mineralized with a distinctive assemblage of metals. Broad east- to east-northeast-trending zones of Precambrian cataclastic rocks are cut by younger fissures that locally contain porphyry dikes and tungsten-molybdenum concentrations of Tertiary age. A 2-mile-wide belt of gouge-filled faults, locally mineralized with copper, extends northeast along the west side of Berthoud Pass; this belt is susceptible to landsliding, and highway and tunnel construction and maintenance within it have been difficult. Younger northerly trending mylonite and breccia zones cut both the Precambrian and the Tertiary intrusive rocks, and locally contain lead and silver deposits.

In studies of Precambrian rocks elsewhere in the Southern Rocky Mountains, Q. D. Singewald has found that the most highly metamorphosed rocks in the Wet Mountains near Westcliffe, Colo., are charnokitic rocks of the granulite facies. These rocks are concentrated in an elongate structural core 2 miles wide that trends northeast across the Mt. Tyndall quadrangle; they are closely associated with, and probably are a somewhat higher grade variant of, the widespread hornblende-pyroxene-plagioclase gneiss of the Wet Mountains.

Two related alkalic intrusive complexes of Precambrian age were mapped by R. L. Parker and F. A. Hildebrand (1–63) in the northern Wet Mountains, Colo. One complex underlies an area of about 2 square miles at Gem Park, 3 miles east of Hillside. The other underlies an area of about 20 square miles and is centered about McClure Mountain, 5 miles northeast of Gem Park. The alkalic rocks range in composition from pyroxenite to nepheline syenite. Carbonatite dikes are present in both complexes, but are most abundant in the Gem Park complex.

Preliminary studies by Fred Barker in the Sawatch Range, Colo., have shown that west of a major mylonite zone the Precambrian rocks are pelitic schist of sillimanite-muscovite grade, much of which contains either cordierite or garnet; and amphibolites, metagabbro, and metamorphosed quartz diorite and granodiorite that contain blue-green hornblende and epidote. East of the mylonite zone are feldspar-quartz-garnet gneisses, amphibolites, and biotite-cordierite-garnet-sillimanite schist that contains no muscovite.

### Stratigraphic and paleontologic studies

A sandstone sequence 82 feet thick at Apache Creek, near the southern end of the Wet Mountains, Colo., has been defined as the Apache Creek Sandstone Member of the Pierre Shale by G. R. Scott and W. A. Cobban (Art. 25). The Apache Creek Member is correlated with the Menefee Formation of the Durango area, Colorado, with the upper part of the Gammon Ferruginous Member of the Pierre Shale in the Black Hills, and with the Sussex Sandstone Member of the Cody Shale in the Salt Creek oil field, Wyoming.

Stratigraphic studies by G. N. Pipiringos in central Wyoming and adjacent parts of Colorado and Utah have established the correlation of the Sundance Formation in Wyoming—divided from the base upward into the Canyon Springs, Stockade Beaver, Hulett, Lak, unnamed B, Redwater, and unnamed A Members—with other stratigraphic units in Colorado and Utah. Southward along the Front Range in Colorado, the upper, unnamed A member intertongues with basal beds of the Morrison Formation, and southwestward it apparently forms part of the Summerville Formation in western Colorado and Utah. The Redwater Member of the Sundance in the Lander area, Wyoming, is identical with the shaly upper part of the Curtis Formation near Vernal, Utah; the slabby ripple- and trail-marked sandstones in the informal B member and the Hulett Member have counterparts in the sandy lower part of the Curtis. The Canyon Springs Member of the Sundance Formation in Wyoming continues southward as the Entrada Sandstone of the Front Range and eastern Uinta Mountains.

G. M. Richmond (2–63) has reexamined the glacial deposits in the Sangre de Cristo Mountains and Sierra

Blanca in New Mexico, and has correlated the several substages previously recognized with the successive glaciations of the Wind River Mountains of Wyoming. Deposits correlative with the Dinwoodie Lake Glaciation, two stades of the Bull Lake Glaciation, and three stades of the Pinedale Glaciation are recognized. Deposits of the Temple Lake Stade of neoglaciation are identified in the Sangre de Cristo Mountains but not in the Sierra Blanca. Deposits of the Gannett Peak Stade are not recognized south of Wheeler Peak in the Sangre de Cristo Mountains.

In mapping the sedimentary rocks of the Mt. Harvard quadrangle northwest of Buena Vista, Colo., M. R. Brock has found a section of Leadville Limestone 150 feet thick that contains no dolomite. This section contrasts with other known exposures of the Leadville in the Sawatch Range, both to the north and south, which contain widespread layers of dolomite. Careful study of the new find should help solve the long-standing question of sedimentary versus hydrothermal origin of the dolomites in the Leadville in and adjacent to the Colorado mineral belt.

A possible equivalent of the Burro Canyon Formation has been recognized by D. L. Gaskill and L. H. Godwin on the Treasure Mountain Dome near Marble, Colo., where a thin conglomeratic quartzite and dense greenish-gray hornfels representing former argillaceous rocks have been mapped near the top of a section generally included in the Morrison Formation. These strata closely resemble some recognized as possible equivalents of Burro Canyon by F. G. Poole along the Grand Hogback to the north.

Well-preserved fossil vertebrates were discovered in the Tertiary rocks of Middle Park, Colo., by G. A. Izett and were studied by G. E. Lewis (Art. 31). The fossils were found in a sequence of soft tuffaceous siltstones and conglomerates that crops out in the Hot Sulphur Springs and Kremmling quadrangles, Grand County, Colo. The few fossils previously reported from this sequence were assigned various ages between Oligocene and early Pliocene. The present study indicates that the stratigraphic position probably is middle Miocene.

In other studies in Middle Park, G. A. Izett, R. B. Taylor, and D. L. Hoover (2–63) have recognized the Windy Gap Volcanic Member of the Middle Park Formation. This member consists of a distinctive sequence of andesitic and trachyandesitic volcaniclastic rocks at or near the base of the Middle Park Formation. No diagnostic fossils have been found in the Windy Gap Member, but a preliminary interpretation based on pollen from an overlying bed of carbonaceous debris indicates that the member is Late Cretaceous in age.

After studying a vertebrate fauna collected from the general type area of the Cutler Formation in southwest Colorado, G. E. Lewis has shown that the formation, previously thought to be either Late Pennsylvanian or Early Permian in age, is Early Permian (Wolfcamp or Autunian), and that it correlates with the lower to middle part of the Wichita Group of Texas.

Detailed studies by D. A. Myers of the Madera Limestone of Pennsylvanian age in the Manzano Mountains, N. Mex., have shown that the lower part of the formation is characterized by advanced forms of the fusulinid genus *Fusulinella* and is late Atoka in age.

### Geology of volcanic and hypabyssal intrusive igneous rocks

In a comparative study of volcanic cauldrons (calderas and volcano-tectonic depressions) associated with voluminous pyroclastic deposits, R. L. Smith and R. A. Bailey [50] have recognized differences in postsubsidence intracauldron vulcanicity that permit classification of such structures into three genetic types: (1) those with mafic to intermediate central volcanoes (Krakatoa, Crater Lake, and Aso calderas), (2) those with mafic and (or) silicic volcanoes, but without central uplifts (Mull and Tibesti calderas), and (3) those with central uplifts and silicic central and ring volcanoes (the Valles caldera, New Mexico, and the Toba depression, Sumatra). They have defined the third type as resurgent cauldrons and pointed out that such cauldrons in the western United States are associated with voluminous ash-flow sheets, and in some places, ore deposits.

Detailed studies were continued in the complex volcanic field of the San Juan Mountains, Colo. In the western part, R. G. Luedke and W. S. Burbank (Art. 70) have redefined the volcanic stratigraphy to conform to new data and interpretations. In and near the ring-fault zone on the northwest border of the Silverton caldera, they have determined that an elliptical block 1 to 2 miles in diameter centered at Red Mountain is downthrown 1 to 2 thousand feet relative to the adjacent rocks. Like other ring-fractured blocks reported by them previously, this one is interpreted to be a product of late magmatic pumping or hydraulic action in the caldera and adjacent areas.

In the central San Juan Mountains near Creede, Colo., T. A. Steven and J. C. Ratté (1–63) have recognized a complexly subsided area at least 25 miles long and 5 to 15 miles wide that shows evidence of at least 4 separate cauldron structures related to voluminous ash-flow eruptions. The area is believed to be the re-

[50] Smith, R. L. and Bailey, R. A., 1962, Resurgent cauldrons—their relation to granitic ring structures and large volume rhyolitic ash flow fields [abs].: Internat. Assoc. Volcanology Symposium on Volcanology Abstracts, p. 67–68; Sci. Council, Japan.

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peatedly disrupted roof of a shallow batholithic magma chamber. Recurrent escape of great volumes of ash led to the collapse of unsupported segments of the roof. Upward movement of magma into the newly subsided blocks caused uplift and local escape of lava.

In mapping the Cimarron Ridge area along the northwest flank of the San Juan Mountains, Colo., R. G. Dickinson has discovered a section of tuff breccia and tuffaceous sedimentary rocks at least 200 feet thick beneath the conglomerates, sandstones, and shales assigned to the Telluride Conglomerate of Oligocene(?) age. The newly discovered volcanic rocks contain plant remains of late Cretaceous or Paleocene age, and they indicate volcanic activity at an earlier stage than had been known previously in this area.

In mapping the Sapinero and Curecanti Needle quadrangles near the Black Canyon of the Gunnison, Colo., W. R. Hansen has found beds of stream gravel between successive Tertiary volcanic flows that overlie Precambrian crystalline and Mesozoic sedimentary rocks. The gravels are all generally similar and consist of fragments of granitic rocks, gneiss, schist, and amphibolite from the Precambrian basement; quartzitic sandstone, siliceous conglomerate, and rare limestone from the Mesozoic sedimentary rocks; and abundant volcanic porphyries. The recurrent deposition of gravel indicates that the Gunnison River and tributaries reestablished themselves after each major volcanic eruption.

Mapping and petrographic studies in the Ruby Range and West Elk Mountains (Anthracite quadrangle) of Gunnison County, Colo., by D. L. Gaskill and L. H. Godwin indicate that the hypabyssal intrusive rocks there probably were derived from the same magmatic source as the dikes, sills, and laccoliths in the adjacent Elk Range to the east. Small stocks and related sills and dikes in the Ruby Range form a sequence that ranges in composition from early hornblende granodiorite through granodiorite porphyry and quartz monzonite porphyry to late granite. Rocks of this sequence cut sedimentary rocks of the early Tertiary Wasatch Formation, but the precise time of intrusion has not been established. Younger hornblende dacite dikes cut the earlier intrusive bodies and volcanic rocks of the West Elk Breccia of Miocene(?) age as well.

In a petrologic study centering on the Mt. Princeton batholith and related intrusive bodies in the southern part of the Sawatch Range, Colo., Priestley Toulmin, III, has found evidence suggesting that the lower part of a volcanic subsidence structure is preserved near Mount Aetna. In this area, rocks thought to be volcanic rather than intrusive lie within the acute angle between two intersecting long dikes of quartz monzonite porphyry. The fracture patterns, evidence of hydrothermal activity, and lithology contrast markedly across the dikes, and the wall rocks outside the dikes are widely sheared.

In the Poncha Springs quadrangle near Salida, Colo., R. E. Van Alstine has mapped two assemblages of Tertiary volcanic rocks that rest on Precambrian metamorphic and igneous rocks and are locally overlain by sediments of early Pliocene age. The older assemblage consists of rhyodacite lava flows and volcanic ash units, followed by quartz latitic and rhyolitic welded tuff. The younger assemblage consists of pumiceous pyroclastic rocks, obsidian, perlite, and partially welded tuff characterized by lithophysae and flattened vesicles containing quartz, sanidine, garnet, topaz, magnetite, and hematite.

#### Structural geology

Geologic mapping by G. O. Bachman in the San Andres Mountains of south-central New Mexico has led to the recognition of a major reverse-fault zone of earlier age than the high-angle normal faults of typical Basin and Range aspect that outline the mountains. The earlier fault zone trends about east across the mountains near San Augustin Pass, and places Precambrian granite across the trend of sedimentary strata of Cambrian to Permian age. Total displacement is at least 5,000 feet.

In the Cameron Mountain quadrangle northeast of Salida, Colo., M. G. Dings has mapped northwest-trending folds and faults in Precambrian and Paleozoic rocks that probably constitute a southern extension of the Mosquito-Weston fault zone, the major structural feature of the Mosquito Range 30 to 40 miles to the north-northwest. A granodiorite stock of Tertiary age several miles wide and about 15 miles long was emplaced along the axis of a syncline in Paleozoic strata, and related hydrothermal solutions deposited copper minerals in the Futurity district in the northern part of the quadrangle.

Downfaulted blocks of the Pliocene Dry Union Formation have been identified by Ogden Tweto along the major Mosquito fault zone, high on the side of the Mosquito Range between Leadville and Climax, Colo. This occurrence indicates that the Dry Union, which now occurs principally in the bottom of the upper Arkansas Valley, once must have nearly covered the adjacent mountains. In addition, it confirms late movement along the Mosquito fault, probably concurrent with previously reported displacements along other faults that cut the Dry Union Formation in the upper Arkansas Valley.

A network of grabens found by A. L. Bush and C. S. Bromfield to be characteristic of the sedimentary terrane along the western border of the San Juan Mountains, Colo., has been found to continue southward in the Dolores Peak quadrangle, where it is marked by a north-northwest-trending graben 5 miles long and 1 to 1½ miles wide. Maximum displacement across the bounding faults is at least 800 feet. In the Dunton mining district, on the western margin of the graben, gold- and silver-bearing veins occupy subsidiary graben faults in rocks of the Cutler Formation of Permian age and the Dolores Formation of Triassic age.

Large-scale block-gliding has occurred widely in the Lake Agnes quadrangle in northwestern Middle Park, Colo., according to W. J. Hail, Jr. Two of the larger blocks are each 2 to 3 square miles in area. They consist largely of sandstone of the Dakota Group which has slid as much as 4,000 feet valleyward over claystone beds of the underlying Morrison Formation.

### Geophysical investigations

Gravity investigations across the upper Arkansas valley near Leadville, Colo., were begun by J. E. Case. The valley is a major tectonic trough of Tertiary age deeply filled by sediments of Pliocene and Pleistocene age. The adjoining Mosquito and Sawatch Ranges consist of Precambrian crystalline rocks and Paleozoic sedimentary rocks injected by many bodies of Tertiary porphyry. Preliminary results from 400 gravity stations indicate a regional low across the central part of the area due to: (1) a residual low of about 20 milligals that reflects the low density of the alluvial and glacial fill in the Arkansas Valley, and (2) a broad low of about 30 milligals that is possibly related to an underlying batholith postulated by many workers in the area.

Preliminary analysis of gravity and magnetic data by H. R. Joesting indicates that major structural features of the Valles caldera and adjoining Rio Grande trough, west of Santa Fe, N. Mex., can be identified beneath the cover of volcanic rocks. Upper Pliocene(?) and lower Pleistocene(?) volcanic rocks display anomalous inverse remanent magnetism that may provide a basis for comparison with volcanic rocks in other areas.

## COLORADO PLATEAU

### Stratigraphy

Preliminary results of mapping in the northwestern part of the Uncompahgre uplift, Utah, southwest of Grand Junction, Colo., by J. E. Case indicate that the Precambrian country rock is dominantly biotite-microcline gneiss of several varieties and variable foliation. The gneiss has been intruded by coarse biotite granite in a body of batholithic size as well as by small plutons of gabbroic rocks and pyroxenite. The metamorphic rocks are weakly magnetic, whereas the biotite granite and the gabbro complex are highly magnetic. These rock units may thus be traced under the cover of sedimentary rocks of Mesozoic age by their characteristic magnetic anomalies.

As a result of the detailed study of the Redwall Limestone, northern Arizona, E. D. McKee (Art. 65) has proposed formal names for the four members of the Redwall widely recognizable in surface and subsurface sections throughout the region. From base to top they are the Whitmore Wash, Thunder Springs, Mooney Falls, and Horseshoe Mesa Members.

Continuing studies by E. D. McKee of the Hermit and Supai Formations, of Permian and Permian and Pennsylvanian age, in northern Arizona have resulted in the discovery of two marker beds in the red-bed sequence. They have now been traced through much of the Grand Canyon. Distributary streams of the Supai apparently flowed southward in this area and formed lobate deltas in a southern marine area rather than in a western marine area as was generally believed heretofore.

The winds that deposited the eolian sandstone of late Paleozoic to middle Mesozoic age in the Colorado Plateau were strong and persistent throughout a broad belt and came dominantly from the north according to F. G. Poole (1–62). The broad belt of northerly winds may represent a former belt of northeast trade winds wider than that of the present, although the belt could have been caused by circulation around a high-pressure cell located over the ancient sea to the west. Other explanations, on the assumption that the trade-wind belt was similar in width to that of the present, require either a northward displacement of the belt because of an expanded equatorial zone, or polar wandering.

In southern Utah and northern Arizona, J. C. Wright and D. D. Dickey (1–63) show that marine and marginal marine beds in the lower part of the Carmel Formation of Middle and Late Jurassic age intertongue with reworked eolian beds of the upper part of the Navajo Sandstone of Late Triassic(?) and Jurassic age. The Thousand Pockets Tongue of the Navajo is as much as 200 feet thick, and it extends northward 70 miles from its source at Kaibito, south of Glen Canyon dam. The source was an anticline that exposed older beds of the Navajo to erosion in Navajo time. D. A. Phoenix [51] has shown that the underlying Judd Hollow Tongue of the Carmel, also as much as 200 feet thick, extends southward 5 to 60 miles beyond the northern edge of the Thousand Pockets Tongue.

Several collections of marine mollusks gathered by W. B. Cashion and identified by W. A. Cobban permit

[51] Phoenix, D. A., 1963, Geology of the Lees Ferry area, Coconino County, Arizona: U.S. Geol. Survey Bull. 1137. [In press]

a more precise placing of the Carlile–Greenhorn boundary (Upper Cretaceous) in part of southwestern Utah. In western Kane County this boundary is in the upper part of the Tropic Formation about 400 feet below the base of the Straight Cliffs Sandstone.

In the Cerro Summit area east of Montrose, Colo., fossils collected by R. G. Dickinson from the Mancos Shale at least 300 feet beneath its top were identified by W. A. Cobban as belonging to the *Didymoceras nebrascense* faunal zone of the Campanian Stage. The coal-bearing beds above the Mancos are therefore probably the same age as the Pictured Cliffs and Fruitland Formations of the San Juan basin.

In the Rio Puerco valley from west of Albuquerque, N. Mex., northward to La Ventana Mesa near Cuba, Carle Dane reports finding a sandstone locally more than 50 feet thick, the top of which is 115 to 150 feet beneath the top of the Juana Lopez Member of the Mancos Shale. Fossils identified by W. A. Cobban suggest that the top of this sandstone is close to the top of the *Collignoniceras hyatti* faunal zone. Preliminary review of the data suggests that the sandstone is extensive and continuous in the southern San Juan basin and may have been derived from a local source in the present southern Nacimiento Mountains.

Additional details have been added by A. B. Olson concerning the intertonguing of the marine Mancos Shale and nonmarine formations of the Mesaverde Group east of the Rio Grande in the Tonque Arroyo–Hagan basin area, Sandoval County, N. Mex. In this area, exposures extend about 8 miles transverse to most of the shorelines of the Cretaceous epicontinental sea and record the following major changes in thickness and lithology:

1. Point Lookout Sandstone thickens southward from 50 feet to 200 feet.
2. The underlying Satan Tongue of the Mancos Shale thins southward from 550 feet to 400 feet.
3. Underlying sandy beds of undifferentiated Mancos Shale grade southward into undivided beds of the Hosta Tongue of the Point Lookout Sandstone, and the Gibson Coal and Dalton Sandstone Members of the Crevasse Canyon Formation. Farther south the Hosta Tongue can be differentiated.
4. The underlying Mulatto Tongue of the Mancos Shale is about 500 feet thick in the area studied. Because of its characteristic sandy composition the Mulatto is recognizable even though the area is entirely seaward from the limit of deposition of the underlying Gallup Sandstone, which is normally diagnostic of the unit.
5. The main body of the Mancos Shale under the Mulatto Tongue thins southward from 540 to about 320 feet.
6. The underlying Juana Lopez Member of the Mancos Shale, and a conspicuous underlying sandstone reported above by Dane, are separated by about 150 feet of Mancos Shale throughout the area.

#### Structural history

Gravity and magnetic surveys in the area containing the junction of the Green and Colorado Rivers, Utah, indicate that a buried structural "high", of probable Pennsylvanian age, extends northwestward from the Colorado River (H. R. Joesting and J. E. Case, 2–62). The trend of this structural high is the same as that of axes of several small surface folds in rocks of post-Pennsylvanian age, and is near the southwest flank of a shallow syncline, but does not coincide with any of these structures. The structural high divides the Paradox basin into a comparatively deep northeast part and a shallow southwest part. Similar conditions in the Uravan area to the east in Colorado were likewise indicated by gravity and magnetic surveys and later were confirmed by drilling. The structural high is crossed by a major structure of northeast strike, marked by gravity and magnetic discontinuities, that extends more than 75 miles along the course of the Colorado River. The structure may be of Precambrian age, and may have been rejuvenated in Pennsylvanian time.

In southeast San Juan County, Utah, well data indicate to R. B. O'Sullivan that strata of pre-Pennsylvanian Paleozoic age thin uniformly eastward across southern Utah. The Hermosa and Molas Formations, of Pennsylvania age, however, thin locally over present major structural features such as the Halgaito, Raplee, and Boundary Butte anticlines. This local thinning, though small, suggests that these prominent folds began to form in Pennsylvanian time.

Pre-Chinle uplift and erosion in middle Triassic time has long been recognized in most parts of the Colorado Plateau. E. D. McKee has available thickness measurements of the Moenkopi Formation on a line between Winslow and Fredonia in northern Arizona (Art. 67), and he demonstrates that a prong extending westward from the Defiance positive area near the Four Corners area was differentially uplifted and subsequently eroded after deposition of the Moenkopi but before deposition of the Chinle.

Two unconformities in southern Utah—one near the base of the Cretaceous strata and the other near the base of the Cenozoic strata—clearly show in regional studies of Jurassic strata, according to J. C. Wright. Beneath the older unconformity, gently northeast-tilted strata of Jurassic age are beveled and are buried under the Dakota Sandstone of Cretaceous age. The regional angularity is revealed by the progressively older Jurassic strata which subcrop beneath the unconformity toward the southwest. The conglomeratic Dakota Sandstone above the unconformity is thin and not exceptionally coarse grained, and it extends for hundreds of miles northeastward. This unconformity is the product of epeirogenic warping that uplifted a southwestern source area and also imposed a pronounced regional slope across a wide area. In contrast, the strata of Mesozoic age beneath the younger, pre-"Wasatch" unconformity in southern Utah are tectonically deformed both along their western margin and along several lengthy monoclinal folds. These structures are truncated beneath the unconformity, but elsewhere associated erosion appears small. Very coarse conglomerate, more than 1,000 feet thick, rests above the unconformity close to its western limit, but the conglomerate thins to 20 feet less than 100 miles to the east. This unconformity is related to localized orogenic deformation to the west, which only imposed a restricted local slope for the eastward transport of conglomeratic material.

Along the Hurricane fault at the western margin of the Colorado Plateau in southwestern Utah, fanglomerate, pediment, and stream-channel deposits range in age from Miocene(?) to Recent. The deposits have been dated by Paul Averitt through studies of the composition and size of gravel components and distance from source of materials. The deposits range in altitude from 6,000 feet at the base of the Hurricane Cliffs on the west or downthrown side of the Hurricane fault, to 9,000 feet on the Kolob Terrace on the east or upthrown side of the fault. Much of the difference in altitude is the result of displacement on the fault in Pliocene and Pleistocene time. Differences in composition of gravel also have established the approximate location of a late Tertiary drainage divide between two westward-flowing streams that formerly headed about 8 miles east of the Hurricane fault. The channels of these streams have since been obliterated by uplift and erosion, and by basalt flows.

### Quaternary geology and physiography

Two important papers describing widely different aspects of Quaternary geology were published by the Survey during the year. J. D. Sears (1–62), describe the development of the canyon of the Yampa River, northwestern Colorado, and G. M. Richmond describe the record of multiple glaciation in the La Sal Mountains, Utah.

The conspicuous "holes" or pockets, such as Brown's Hole, on the north wall of Yampa Canyon have been termed "meander-migration scars." Their origin is attributed to the downdip migration and lowering of early meanders of the Yampa River that formed on the depositional surface of the Browns Park Formation of Miocene(?) age as the river incised its way into the southern flank of the Uinta Mountain arch in close accordance with preexisting graben structure and relative resistance of the underlying Weber and Morgan Formations.

G. M. Richmond [52] recorded at least 6 glaciations of Pleistocene age and 2 minor cirque glaciations of Recent age in the La Sal Mountains of eastern Utah. He recognized and delineated 4 formations of Quarternary age characterized by distinctive soil profiles, relative topographic position, surface expression, internal character, and relation to erosion surfaces and disconformities.

W. R. Hansen examined a deposit of ash, 5 to 6 feet thick, uncovered in an excavation for road gravel near Sapinero, Colo., on the eastern margin of the Colorado Plateau. Analyses by E. J. Young of the Geological Survey indicate that the ash, which contains chevkinite and green ferroaugite, is mineralogically similar to, and therefore probably correlates with, the Pearlette Ash Member of the Sappa Formation of late Kansan age. The ash is 200 feet above the Lake Fork of the Gunnison River on a terrace mantled by at least 8 feet of cobble gravel of Pleistocene age. The ash is overlain and truncated by tuffaceous silty sand and gravel about 12 feet thick that has a calcareous soil profile and is apparently pre-Wisconsin in age. The silty sand and gravel are in turn overlain by 3 feet of silty colluvium of late Wisconsin or possibly Recent age. The indicated rate of downcutting in Lake Fork Canyon since deposition of the ash is on the order of one foot in 1,000 years.

At the western edge of the Gunnison uplift, south of the Black Canyon of the Gunnison River, Colo., preliminary study indicates to R. G. Dickinson the presence of sediments of pre-Wisconsin and of Wisconsin age that were previously mapped by Atwood and Mather and designated by them as the Florida Gravel of pre-Wisconsin age. Soil profiles were developed in about 200 feet of alluvial gravel and colluvium in the once-continuous but now bisected Shinn Park and Bostwick Park valleys. The sequence of beds indicates that a sizable stream, perhaps the ancestral Uncompahgre River, once flowed northwestward through the valley to the Gunnison. This river was probably beheaded

[52] Richmond, G. M., 1962, Quaternary stratigraphy of the La Sal Mountains, Utah: U.S. Geol. Survey Prof. Paper 324.

early in Pleistocene time by a stream in the present Uncompahgre Valley through rapid headward erosion in the Mancos Shale. This drainage was in turn bisected by the present Cedar Creek in late Wisconsin time.

A series of low straight subparallel scarps that are oriented about N. 25° E. bound elongate flat areas in loess of pre-Wisconsin age on the Sage Plain, southwestern Colorado. The scarps were interpreted as fractures by V. C. Kelley in 1955, but D. R. Shaw finds no relation to underlying rock structure (Art. 95). The flat areas are nearly at the level of an old weathered surface, and swales between the flats probably have been deflated by prevailing southwesterly winds.

## BASIN AND RANGE REGION

### Precambrian geology in Arizona

Further study of the granodiorite gneiss, discovered by P. M. Blacet to lie unconformably below the Yavapai Series, suggests that the gneiss corresponds to a period of orogeny about 1,750 million years ago. Although K-Ar and Rb-Sr ratios from micas in the gneiss indicate an age of about 1,250 million years (analyses by Carl Hedge), measurements of isotopes of lead in zircon from the gneiss indicate a minimum age of 1,700 million years (analyses by E. J. Catanzaro), more in keeping with stratigraphic relations. The micas apparently recrystallized during a period of deformation known to have effected the overlying Yavapai Series, but the zircons of the gneiss seem to have remained unaltered.

### Stratigraphy in Arizona

In the Huachuca Mountains of southeastern Arizona, P. T. Hayes has recognized several subdivisions of the Bisbee Group of Early Cretaceous age, and preliminary study indicates that volcanic rocks of unknown thickness in the area are of pre-Bisbee post-Permian age. Harald Drewes in early phases of an investigation of the Mount Wrightson area finds that the pre-Bisbee sequence of volcanic and sedimentary rocks is at least partly of subaqueous origin.

Stratigraphic investigations by T. L. Finnell along Canyon Creek in southwestern Navajo County, Ariz., have shown that rocks formerly thought to be Troy Quartzite and considered to be of Cambrian age, actually include two units—one a quartzite of Precambrian age and the other a sandstone of early Paleozoic age—separated by a major unconformity. The unit of Precambrian age, to which the name Troy Quartzite is now restricted, was intruded by diabase before deposition of the unit of early Paleozoic age. The lower Paleozoic standstone fills the lower 150 feet of 3 broad valleys that were cut as much as 450 feet into the Precambrian terrane.

By measuring stratigraphic sections in the American Peak-Mowry mine area of the Harshaw quadrangle northeast of Nogales, southern Arizona, F. S. Simons found that rocks of Paleozoic age are at least 4,300 feet thick, and include the Bolsa Quartzite, Abrigo Limestone, Martin Limestone, Escabrosa Limestone, Horquilla Limestone, Earp Formation, Epitaph Dolomite, Scherrer Formation, and Concha Limestone. These formations thus extend at least 45 to 55 miles west and southwest of their type localities in the Mule Mountains, Tombstone Hills, and Gunnison Hills.

### Structural geology in Arizona

M. H. Krieger has found that the Miocene(?) Galiuro Volcanics have been dropped down 2,000 to 3,000 feet along the fault or faults bounding the east side of the San Pedro Valley between Mammoth and Winkelman, Ariz. Major displacement on the faults took place during accumulation of the Gila Conglomerate, and there was minor movement in post-Gila time.

Harald Drewes has found a large northwest-trending fault zone, along which there has been right-lateral displacement and local thrust movement, near Sawmill Canyon in the Mount Wrightson area north of Nogales, Ariz. Parts of what may be the same fault zone to the southeast have been identified by R. B. Raup in the Elgin quadrangle and by P. T. Hayes on the southwestern flank of the Huachuca Mountains.

Reconnaissance study by E. F. Pashley, Jr., of the structure of the layered gneissic rocks of the Rincon, Tanque Verde, and southern Santa Catalina Mountains east of Tucson has delineated a series of simple doubly plunging anticlines and synclines whose axes trend N. 60° to 65° E., rather than northwest or west-northwest as thought by previous workers. Pashley suggests that the folding and metamorphism took place in middle Tertiary time.

### Stratigraphy in Nevada

A sequence of vanadium-bearing Devonian shales and sandstones in the southern Fish Creek Range, southwest of Eureka, Nev., has been found by T. B. Nolan and C. W. Merriam to contain land plants, spores, Mollusca, eurypterid claws, and goniatites. The vanadium-bearing shales and sandstones, doubtless land laid in part, probably intertongue with more nearly normal marine parts of the Nevada Formation. Fossil evidence and lithology invite comparison of this newly recognized sequence with facies of the Catskill Formation of New York and the Old Red Sandstone of Europe.

A study by R. C. Douglass of the reference section of the Pequop Formation proposed in 1961 by G. B.

Robinson, Jr., in northeastern Nevada suggests that the section may be repeated and that the upper beds may not be of as late a Permian age as was formerly supposed.

During geologic exploration of northern Nye County, Nev., F. J. Kleinhampl discovered in the Hot Creek Range a sequence of Paleozoic rocks having affinities with both eastern (miogeosynclinal) and western (eugeosynclinal) facies farther north in Nevada. These transitional rocks consist of siliceous shale and siltstone, argillite, chert, subgraywacke, and shaly to massive limestone. Locally the transitional rocks rest on carbonate rocks of the eastern facies in a thrust relation similar to that along the Roberts Mountains thrust farther north.

A search by R. C. Douglass of exposed strata representing geologic time near the Pennsylvanian-Permian boundary in an area south of Ely, Nev., indicated that Upper Pennsylvanian rocks probably are discontinuous. Rocks of Late Pennsylvanian age have been found in a limited area east of Lund, but not in most of the exposed sections in the main body of the Egan Range.

R. E. Wallace, N. J. Silberling, and D. B. Tatlock discovered a boulder conglomerate in the Rochester Rhyolite near Cottonwood Canyon in the Humboldt Range, western Nevada. The conglomerate contains principally rhyolite clasts of Kiopato Group rocks, but also some clasts of quartzite and some sandy limestone. Nearby active erosion of the Kiopato volcanic pile is implied as well as exposure to erosion of older Paleozoic rocks.

Overthrust Ordovician, Silurian, and Devonian rocks and post-thrust Lower Mississippian rocks in the Railroad district near Carlin, Nev., have been studied and analyzed by K. B. Ketner and J. Fred Smith, Jr., (Art. 13) and found to be largely siliceous mudstones containing 63 to 94.5 percent $SiO_2$ and 1.1 to 13.0 percent $Al_2O_3$.

### Structural geology in Nevada

The complex structural geology of Nevada continues to be a major challenge, and several important analyses and interpretations highlighted this year's progress. For example, J. P. Albers and J. H. Stewart defined an oroclinal or horseshoe-shaped fold system in western Nevada, crudely marked by the Silver Peak and Palmetto Mountains and other arcuate ranges. This fold system implies large-scale lateral flexing as a major style of deformation along a northwest-trending zone 50 to 100 miles wide and at least 250 miles long adjoining the Sierra Nevada on the east. The Walker Lane, described by Locke, Billingsley, and Mayo,[53] is included within this zone. The oroclinal flexing, together with at least three major strike-slip faults distributed across the zone, indicates that the zone is one of extreme structural mobility and a "hinge-line" of major importance in the western Cordillera.

Low-angle faults of various types have been identified in more and more areas of the eastern Basin and Range province. In the Schell Creek Range southeast of Ely, Nev., Harald Drewes has distinguished low-angle gravity faults, formed near the surface, from low-angle thrust faults, and has found that relatively young normal faults are locally deflected along segments of major thrust faults. In the Snake Range, D. H. Whitebread has recognized a major décollement thrust, and from a structural analysis has found that the thrust truncates the upper part of the large granitic mass in the range. The intrusive rocks are from middle to late Mesozoic age; thus Whitebread believes that the faulting probably is no older than Cretaceous.

An analysis of structure of the Diamond Mountains of eastern Nevada by D. A. Brew shows in the south-central part of the range a concentration of asymmetrical and overturned folds, characterized by west-dipping axial planes, which together with stratigraphic evidence implies relatively greater structural shortening than elsewhere in the range. At Black Point, near the southwest end of the more compressed block, T. B. Nolan has identified west-dipping thrusts and high-angle transverse faults.

### Volcanic rocks in Nevada

In a study of volcanic rocks near Beatty, Nev., H. R. Cornwall estimates that about 85 cubic miles of ash-flow material erupted from the larger of two calderas, measuring 10 by 13 miles, and that the subsidence was about 3,500 feet, measured along a fault on the east rim. The volume of the subsidence was about equal to the volume of the ash flow indicating that the caldera subsided by this amount to fill a void left by the extrusion of the ash flow.

An outgrowth of D. B. Tatlock's study of metasomatism of the Koipato volcanic rocks of the Humboldt Range and his reconnaissance of Pershing County, Nev., has been the recognition that silicic extrusive rocks ranging in age from late Paleozoic to early Mesozoic are considerably more abundant and widespread in the western Cordillera than has been previously suspected. Almost all these silicic rocks exhibit an extreme ratio in alkali content, rather being either highly potassic or highly sodic. In contrast, unaltered Cenozoic salic volcanic rocks exhibit a ratio near 1:1 in alkali content.

J. W. Allingham has found that in the Nevada Test Site of southern Nevada the Oak Spring tuff sequence

[53] Locke, Augustus, Billingsley, P. R., and Mayo, E. B., 1940, Sierra Nevada tectonic patterns: Geol. Soc. America Bull., v. 51, p. 513–539.

locally has strong remanent magnetization, and he believes that large negative magnetic anomalies in the area are underlain by some unit of the Oak Spring Group which has reverse remanent magnetization.

A large magnetic anomaly in central Nevada was found by D. R. Mabey in an aeromagnetic study of the Roberts Creek Mountains, Cortez Range, and the northern Shoshone Range. The anomaly correlates with a swarm of basaltic dikes and related flows which have been the subject of investigation by Harold Masursky in the Cortez Range, and the continuity of the anomaly from range to range implies that the dike swarm has a similar continuity.

#### Stratigraphy and structural geology in Utah

In the Wasatch Range east of Salt Lake City, Utah, M. D. Crittenden, Jr. (Art. 24), has found that stratigraphic units formerly believed to be of Jurassic age are in fact of Late Jurassic and Early Cretaceous age, and should be assigned to the Kelvin Formation. Crittenden redefines the Kelvin Formation to include two members.

An analysis of the structure of the Wasatch Range between the Traverse Range and Brigham City by Crittenden emphasizes the influence upon later deformation exerted by the Uinta axis and the Wasatch line, both of which had their origin in late Precambrian time. After the west end of the Uinta trough was pushed deep into the crust beneath the Oquirrh basin, the block west of the Wasatch line was uplifted and slid eastward across the line onto the edge of the former shelf. At least four separate successive pulses of thrusting can be distinguished in the Wasatch, Oquirrh, and Stansbury Mountains by the superposition or truncation of faults and folds.

According to E. W. Tooker and R. J. Roberts (2–63) an east-trending narrow zone of deformed rocks, the Pass Canyon sequence, underlies the North Oquirrh thrust in the Oquirrh Mountains south of Great Salt Lake, Utah, and is in turn separated from simply folded Bingham sequence rocks by the east-trending Pass Canyon thrust. Later, north and northwest-trending tear and normal faults cut all sequences.

Bouguer anomaly values obtained by D. R. Mabey increase north of the trace of the North Oquirrh thrust under the Rogers Canyon sequence, but are nearly constant southward, suggesting that dense basement rock is closer to the surface under the Rogers Canyon sequence. Two explanations are offered: (1) basement rock may be displaced upward on the North Oquirrh thrust, or (2) overlying sediments thin rapidly northward from the outcrop of the thrust. Magnetic data seem to eliminate the possibility that the gravity anomaly is caused by concealed intrusive rocks (Mabey and others, 2–63).

#### Stratigraphy and structural geology in California and Nevada

In an analysis of the Paleozoic stratigraphy of the Inyo Mountains, Calif., D. C. Ross (Art. 21) has defined two new Upper Cambrian formations, the Lead Gulch Formation and the Tamarack Canyon Dolomite, which are tentatively correlated with the Nopah Formation. He also has proposed that the Mazourka Group of Middle and Early Ordovician age be raised to group status, and that Silurian facies in the Independence quadrangle be named the Vaughn Gulch Limestone.

In an investigation of the New York Butte quadrangle and adjacent areas in the Inyo Mountains, W. C. Smith has made a special study of Triassic rocks, and has found that two distinct units can be recognized. The older unit consists of marine limestone and shale as much as 3,000 feet thick and contains fossils of medial Early Triassic age near the bottom and fossils of earliest Middle Triassic age near the top. The younger unit, which consists of unfossiliferous continental sedimentary and volcanic rocks, disconformably overlies the marine unit and is probably of Middle or Late Triassic age. The exposed section of the upper unit is at least 7,000 feet thick.

T. W. Dibblee, Jr., has discovered in the Newberry Mountains of the central Mojave Desert that a great pile of lava flows, breccias, and fanglomerates, as much as 15,000 feet in aggregate thickness, and of Miocene or older age, onlaps westward and southward against an erosion surface of enormous relief. Stratification planes within the pile intersect the underlying erosion surface at angles as high as 50° with no evidence of faulting. From this and other evidence Dibblee has concluded that the thick sequence rapidly accumulated adjacent to a very high rugged mountain range.

An abrupt change in the facies of Cambrian strata has been found by J. H. Stewart in the Eureka Valley and Last Chance Range region in the eastern part of Inyo County, Calif. In the southern part of this region the Cambrian sequence consists of the Wood Canyon, Zabriskie of Hazzard, 1937, Carrara, Bonanza King, and Nopah Formations, whereas in the northern part of the region, strata of comparable age but of different facies consists of the Campito, Poleta, Harkless, Mule Spring, and Emigrant Formations. Strata of these two facies lie within 10 to 15 miles of each other.

Similarly, D. C. Ross has found pronounced and rather rapid facies changes in Silurian rocks of the Independence quadrangle, eastern California, which reflect a northwestward change from the eastern carbonate assemblage to a transitional assemblage (Art. 21).

Study of the Middle Ordovician stratigraphy of southern Nevada and adjacent California by R. J. Ross indicates that the areas of deposition of all Middle Ordovician lithic units including the *Palliseria*-rich middle member of the Antelope Valley Limestone migrated westward with time. In addition to westward movement, the area of deposition of the Eureka Quartzite can be shown to have migrated southward along the miogeosynclinal tract, and Ross believes that this evidence indicates a northerly source for Middle Ordovician sands rather than a strict cratonic eastern source as has been believed.

### Cenozoic rocks and history in Utah

R. B. Morrison and G. M. Richmond have found in new excavations in the Bonneville shore terrace below the mouth of Little Cottonwood Canyon, Utah, that a mature soil was developed on till and outwash of the Bull Lake Glaciation. This evidence demonstrates a post-Bull Lake rise of the Bonneville shoreline, presumably during the Pinedale Glaciation.

At Little Valley near the southern end of Promontory Point, Utah, R. B. Morrison has recognized evidence of two pre-Lake Bonneville lake cycles which were comparable in magnitude to Lake Bonneville. The first of these major cycles is probably of Kansan age, the second probably of Illinoian age.

Elsewhere in the province, evidence of pre-Wisconsin, possibly Illinoian lakes also was discovered by G. I. Smith in the south part of Searles Valley, Calif., in addition to subsequent multiple lake cycles of early, middle, and late Wisconsin and Recent ages. Smith also finds that soil horizons present in the Searles Lake area correlate in both stratigraphic position and relative intensity with the soils found elsewhere in the western United States, and he supports the belief of Morrison and others that soils can be used as a "time line" during this part of geologic history.

## COLUMBIA PLATEAU AND SNAKE RIVER PLAIN

### Stratigraphy and paleontology in Oregon and Idaho

Reconnaissance mapping by G. W. Walker and C. A. Repenning in the Steens Mountain area of southeastern Oregon helps to resolve the apparent conflict in previous concepts of stratigraphy in this region. Their mapping demonstrates that the Alvord Creek Formation, which contains a fossil flora described as Pliocene by Axelrod in 1944, is faulted and may correlate with beds that laps against the volcanic rocks of Steens Mountain. Also, near Fields to the south of Steens Mountain, they have collected fossil mammals of early to middle Pliocene age from gravel deposits formerly considered to be older Quaternary alluvium. These gravels lap and are faulted against the volcanic rocks of the Pueblo Mountains, and appear to be stratigraphically related to the Alvord Creek Formation. Previously, the Pliocene Alvord Creek Formation was thought to underlie the volcanic rocks of Steens Mountain; the volcanic rocks of Steens Mountain are now known to be Miocene and Oligocene(?) from evidence in other nearby localities.

In the structural block to the east of the Steens Mountain–Pueblo Mountains block, the little-deformed Trout Creek Formation of Smith, 1926, contains two mammal faunas of late Miocene age. Overlying these beds are flows of dictytaxitic basalt that have been traced across undeformed exposures eastward into the vicinity of Rome, Oreg., where they underlie fossiliferous Pliocene sedimentary rocks.

Ammonites from the Wallowa Mountains of northeastern Oregon have been identified by Ralph W. Imlay as being of Early Jurassic age, thus establishing the first recognition of Jurassic in the Wallowa Mountains.

From the Snake River Canyon, Idaho, near the Oregon–Washington boundary, ammonites are identified by Imlay as early Oxfordian (earliest Late Jurassic) age. Previously, beds of this age have not been identified from the Pacific Coast States farther south than British Columbia.

From his study of large collections of fossils from the lacustrine facies of the Glenns Ferry Formation, late Pliocene and early Pleistocene, of southwestern Idaho, Dwight W. Taylor reports (Malde and Powers, 1–62) that nearly all the fresh-water mollusks belong to extinct species (94 percent), and a large number belong to extinct genera. In degree of endemism, in the variety of species and genera, and in the great variety of individual forms, the Glenns Ferry mollusks are similar to those living in Lake Ohrid, Yugoslavia, and in Lakes Tanganyika and Nyassa, Africa, as well as to the fossil assemblages from the Pliocene deposits of the Pontian, Dacian, and Levantine basins of southeastern Europe.

### Geologic aspects of Columbia Basin Irrigation Project in Washington

Reconnaissance mapping of the sediments in the area covered by the Columbia Basin Irrigation Project, Wash., by J. W. Bingham (see also p. A45) has shown the Touchet Beds of Flint to be present in the Quincy Basin above an altitude of 1,310 feet. The beds contain ice-rafted erratics up to about 1,350 feet, which indicates the presence of another glacial lake approximately 200 feet above glacial Lake Lewis. The clastic dikes in the Touchet have long been known, but new exposures in the Pasco Basin show the dikes to have a polygonal pattern in plan view, which suggests shrinkage, possibly by drying. Also, several localities were found where clastic dikes of Touchet-type materials have penetrated the underlying caliche and Ringold Formation as much as 150 feet.

Geologic mapping by M. J. Grolier and cross sections compiled by J. W. Bingham show that the basalts exposed in the Pasco Basin and the east end of the Saddle Mountains are stratigraphically above the Yakima Basalt. In the Othello Channels, three or more flows above the Yakima yield adequate water to most domestic wells, but the average is less than for wells in the Yakima Basalt.

### Natural radioactivity studies in Idaho

Natural radioactivity levels, determined from aerial survey measurements over the area of the National Reactor Testing Station, Idaho, range from 2200 cps to 200 cps. The highest radioactivity levels are associated with outcrops of silicic volcanic rocks, and the lowest level of activity was measured over alluvium along the northeast shore of American Falls reservoir.

The areal extent of some Quaternary lake sediments, and of Recent basalt flows is adequately outlined by the radioactivity data as interpreted by R. G. Bates. The uniform radioactivity levels of several of the Recent basalt flows suggests their origin from a common magma source, whereas variation of levels over several other Recent basalt flows suggests their origin from a number of differentiated sources.

## PACIFIC COAST REGION

### Washington

In the northeastern Olympic Mountains, a persistent fossil zone was discovered by W. M. Cady and N. S. MacLeod approximately 15,000 feet below the base of the Crescent Formation of early(?) and middle Eocene age. The fossil zone, which crops out intermittently for about 21 miles along the strike, is 500 to 1,000 feet thick, and is characterized by alternating thinly cross-laminated siltstone and finely brecciated black argillite containing fragments of megafossils. The fossils, which include *Acila* cf. A. decisa (Conrad), *Crassatella?* sp., and *Gemmula?* sp., were identified by W. O. Addicott and assigned a possible early Tertiary, Paleocene to Eocene age. The discovery shows that a considerable part of the graywacke, argillite, slate, and mafic volcanic rocks that form the core of the Olympic Mountains is early Tertiary in age, rather than Cretaceous(?) as previously thought.

Studies of surficial deposits in Mount Rainier National Park by D. R. Crandell (Art. 36) revealed an unsorted till-like deposit overlying late Wisconsin drift in the Paradise Peak area on the south side of Mount Rainier. The deposit is inferred to be a debris flow formed by an avalanche from the summit of the Mount Rainier volcano. This avalanche, as well as another that formed the apparently contemporaneous 4,800-year-old Osceola Mudflow on the northeast side of the volcano, possibly originated in an explosive eruption that destroyed the former summit of Mount Rainier.

Recently completed geologic mapping of the Glacier Peak quadrangle in the Northern Cascade Mountains by D. F. Crowder, R. W. Tabor, and A. B. Ford suggests a common structural control for the feeders of the Glacier Peak volcano and the quartz diorite of the Cloudy Pass pluton. This pluton, which cuts Paleocene and older rocks, was intruded to a high level in the earth's crust. Biotite from the quartz diorite of the Cloudy Pass pluton gives a potassium-argon age of 22±2 m.y. according to R. F. Marvin. Lead-alpha ages of zircon concentrates as reported by T. W. Stern support this age, although the lead-alpha method is not well adapted to such young rocks. A zone of stocks and dikes of quartz diorite and intrusive breccia extends southwest from the pluton across the regional strike and directly underneath the volcano, which consists of Quaternary lavas partly mantled by Recent pumice.

Geologic mapping by F. W. Cater, T. L. Wright, and D. F. Crowder in the Lucerne quadrangle has yielded additional data on the core of the Northern Cascade Mountains. Within this quadrangle the core is composed entirely of metamorphic rocks intruded by later plutons and dikes. The metamorphic rocks consist of migmatite, gneiss, schist, quartzite, and a little marble. They have been derived from a sequence of volcanic and sedimentary rocks several miles thick, and they form the southwest limb of a large anticline. The plutonic rocks occur as roughly concordant northwest-trending masses of granodiorite and quartz diorite which are believed to be related to the Chelan batholith.

### Oregon

In the northwestern part of the Oregon Coast Range, geologic mapping by P. D. Snavely, Jr., and H. C. Wagner, together with petrographic studies and analysis of new chemical data, indicates that the sill of granophyric gabbro at Neahkahnie Mountain, its attendant dikes, and an overlying thick sequence of pillow basalt and breccia, all belong to the same magmatic episode. Regional relations show the late Miocene age of the pillow basalt sequence, and hence of the Neahkahnie sill. As the sill is almost identical petrographically and chemically with the large sills in the central part of the Oregon Coast Range, a late Miocene age is suggested for them also. The pillow lavas and breccia and the chilled border facies of the sills are very similar in mineralogy and chemical composition to the Yakima petrographic type of the Columbia River Basalt.

In a paper of regional scope, Snavely and Wagner (1–63) summarized the Tertiary geologic history of western Oregon and Washington, presenting much of their analysis graphically in a series of paleogeologic maps. At the beginning of the Tertiary Period, the area was the site of a north-trending eugeosyncline that extended southward from Vancouver Island to the Klamath Mountains. During early Eocene time, a thick sequence of tholeiitic pillow lavas and breccia was erupted from numerous fissures onto the floor of the rapidly subsiding eugeosyncline; these extrusive rocks interfingered with marine ashy silt and volcanic sands. In middle Eocene time, major uplift and erosion in the ancestral Klamath Mountains resulted in an influx into the southern part of the basin of great quantities of arkosic detritus, much of which was transported northward into the deeper parts of the eugeosyncline by turbidity currents. In late Eocene time, local uplift and extrusion of alkalic basalt divided the geosyncline into several separate basins of deposition. Tuffaceous sandstone and siltstone accumulated within these basins from the late Eocene to the Pliocene, and the general axis of sedimentation shifted westward with time. Concurrently with the deposition of middle Miocene marine sediments, basalt flows and breccia were extruded onto the sea floor from a north-trending group of vents near the strand line, and flood basalts of similar composition flowed down the Columbia River downwarp.

### Coast Ranges and Klamath Mountains of California

Studies by Bailey, Irwin, and Jones [54] of the lithology and distribution of thick sequences of rocks of Late Jurassic and Cretaceous age in the California Coast Ranges show that the rocks are divisible into two lithologic asemblages: a eugeosynclinal assemblage which includes the Franciscan Formation, and a flysch-like assemblage which includes the strata of the Central Valley. They suggest that the eugeosynclinal rocks were deposited directly on a mafic or ultramafic substratum, possibly in a basin formed by major crustal rifting,[55] whereas the Flysch-like sequence was deposited on the continental shelf and slope. The present distribution of these rocks cannot be explained by depositional facies changes alone, and therefore must be the result of major tectonic dislocations such as major east-west thrust faulting, large-scale strike-slip movements, or combinations of these.

The major anomalies in a gravity survey by W. G. Clement of the northern part of the San Francisco Bay area come from density contrasts between Tertiary and pre-Tertiary rocks; and within the pre-Tertiary rocks, between Franciscan sedimentary rocks and interbedded volcanic rocks or intruded ultramafic rocks. There is no characteristic local gravity expression of the San Andreas fault. The downfaulted block of Tertiary rocks of the San Pablo basin gives a prominent negative anomaly, and the western gradient of this anomaly indicates that the Tolay fault is the northward extension of the Hayward-Wildcat fault zone.

Analysis by G. D. Bath of data from an aeromagnetic survey of the San Francisco Bay area shows that large masses of sandstone of Miocene, Pliocene, and Cretaceous age are sufficiently magnetic to produce anomalies of 10 to 60 gammas at an elevation of 1,000 feet above the outcrops. The magnetization of collected samples of sandstone indicates a content of 1 percent magnetite; this magnetite content was verified by careful mineral separations from a few samples by Julius Schlocker. The ability of the airborne magnetometer to detect the near-surface position and to indicate the structure of large masses of magnetic sandstone offers an opportunity for low-cost exploration for oil and gas structures in adjacent areas covered by alluvium and water.

Geologic mapping by P. E. Hotz in the Condrey Mountain quadrangle, Siskiyou County, suggests that a metamorphic complex of amphibolite schist and marble, previously regarded as a regionally metamorphosed facies of the Applegate Group of Triassic age, is older than the weakly metamorphosed rocks of the Applegate Group, and is separated from them by a thrust or high-angle reverse fault. A large sill of granitic rock and many smaller igneous bodies have been emplaced along the fault.

### Sierra Nevada, Cascade Range, and San Joaquin Valley in California

R. W. Kistler (1–63) has described an unusual caldera, approximately 8 miles in diameter, that causes an embayment in the eastern frontal scarp of the Sierra Nevada southeast of Mono Lake. The eastern edge of the caldera is marked by the Recent rhyolite domes of the Mono Craters, by Pleistocene basaltic cinder cones, and by andesitic flows of possible Tertiary age. The western edge is a vertical shear zone, locally intruded by rhyolite dikes, that is the protoclastic border of a Cretaceous quartz monzonite pluton occupying the center of the caldera.

[54] Bailey, E. H., Irwin, W. P., and Jones, D. L., 1963, Franciscan and related rocks and their significance in the geology of western California [preprint of abs. and map]: Sacramento Geol. Soc. guidebook for field trip to Pacheco Pass. [In press]

[55] Bailey, E. H., 1963, Mesozoic sphenochasmic rifting along the San Andreas fault north of the Transverse Ranges [abs.]: Geol. Soc. America Cordilleran Section, 59th Mtg., Program, p. 18–19.

As the result of geologic studies in Yosemite National Park, D. L. Peck has outlined a series of 3 closely related granitic plutons that are exposed near Washburn Lake over an area of about 35 square miles. The plutons are arranged in plan like a target, with the youngest pluton at the center and the oldest at the rim. Each is separated by a sharp contact, along which schlieren and dikes indicate the relative ages. The core of the series is a body of felsic quartz monzonite porphyry, which is surrounded by a pluton of coarser grained, more mafic biotite quartz monzonite that contains abundant phenocrysts of K feldspar; this pluton in turn is bordered by a somewhat similar granitic rim that grades outward from biotite quartz monzonite to hornblende granodiorite. The series is thought to have formed from a single body of magma that solidified progressively inward from the margins; at two intervals during the solidification, the still-mobile core intruded the solidified outer margin, causing sharp contacts between the members of the granitic series. Later the entire series was bisected by a Half Dome Quartz Monzonite dike, 1 to 2 miles wide, which forms the walls of the Merced River Canyon.

Current work by N. K. Huber and C. D. Rinehart shows that the Cenozoic volcanic history of the Mammoth Lakes area of the Sierra Nevada is much more complex than previously recognized, and includes at least 10 separate episodes of volcanic activity ranging in age from Pliocene to Recent. Conclusions reached in the current study are similar to Matthes' original interpretations of the development of the San Joaquin drainage system and the age of the "Broad Valley" and "Mountain Valley" erosion surfaces, thus differing from recently published suggestions that these surfaces are both Pleistocene in age. One of the more interesting volcanic formations in the area is a basaltic flow that locally exhibits extraordinarily well developed columnar jointing, the most striking exposure of which has been dedicated as the Devils Postpile National Monument. Earlier workers concluded that the flow was erupted during the last interglacial epoch, but potassium-argon dating now indicates that it is older and that it was erupted approximately 1 million years ago.

A narrow gravity anomaly of 30-mgals amplitude in northern Owens Valley was described by Pakiser and Kane.[56] Geologic mapping by Bateman (2–62) and analysis of the anomaly show that the valley is underlain by a narrow trough filled with Cenozoic clastic deposits to depths as great as 8,000 feet. The eastern side of the trough is bounded by a near-linear fault zone at the base of the White Mountains, but the western boundary is more complex and irregular, the expression of both block faulting and warping. Near Bishop the base of the trough is 5,000 feet below the eastern side of the valley; to the west the base rises gradually to merge with the surface of the Coyote downwarp.

A Bouguer gravity anomaly with total amplitude of about 90 mgal was mapped by T. R. LaFehr and L. C. Pakiser across the Klamath Mountain–Cascade Range boundary in north-central California. Gravity gradients average about 6 mgal per mile and in places are as steep as 10 mgal per mile. The residual gravity anomaly is a broad low, about –30 mgal in amplitude, which covers about 1,300 square miles in the vicinity of Mt. Shasta. Preliminary depth calculations indicate that the mass deficiency causing the gravity low must be largely within the upper 9 miles of the earth's crust, and that the top surface of the density contrast is probably less than 6 miles deep. The investigation suggests that the Mt. Shasta part of the Southern Cascades is in approximate isostatic equilibrium.

Oliver and Mabey[57] have prepared a Bouguer gravity map of east-central California using about 11,000 gravity stations, which range from –14 to –274 mgal. Gravity lows in the San Joaquin Valley and over local basins south and east of the Sierra Nevada are produced by large thicknesses of Upper Cretaceous and Cenozoic deposits. A large regional gravity low over the Sierra Nevada can be explained by isostatic compensation of the range together with the effects of the relatively low-density rocks of the Sierra Nevada batholith. A broad gravity ridge along the east side of the San Joaquin Valley correlates with a similar magnetic ridge, suggesting that both are caused by dense, magnetic rocks at an estimated depth of 5–10 miles.

In an investigation of the ground-water resources of the Kings and Kaweah River alluvial fans of the east-central San Joaquin Valley, M. G. Croft divided the late Tertiary and Quaternary deposits into 2 units. The upper unit is coarser than the lower, and both interfinger with 5 lacustrine deposits in the valley trough. The maximum depth to the base of the upper unit is 700 feet and to the base of the lower unit is 3,000 feet.

Four extensive lacustrine clay zones, 2 in the upper unit and 2 in the lower unit, subdivide the alluvial deposits; the lower clay zone of the upper unit is the Corcoran Clay Member of the Tulare Formation.

G. H. Davis and J. H. Green (2–62) interpret the thick lacustrine deposits in the trough of the San Joaquin Valley at Tulare Lake Bed as indicating continued

[56] Pakiser, L. C., and Kane, M. F., 1962, Geophysical study of Cenozoic geologic structures of northern Owens Valley, California: Geophysics, v. 27, p. 334–342.

[57] Oliver, H. W., and Mabey, D. R., 1963, The anomalous gravity field in east-central California; Geol. Soc. America Bull. [In press]

downwarping of a synclinal structure paralleling the Kettleman Hills anticline during the time interval represented by the upper 3,000 feet of deposits. In the axis of the syncline the structural closure on the top of the Corcoran Clay Member of the Tulare Formation is about 300 feet compared to a topographic closure of about 30 feet at the surface.

R. E. Miller, in land-subsidence investigations of the central west side of the San Joaquin Valley recognized three widespread lacustrine zones in the late Tertiary and Quaternary section. The uppermost is represented by the Corcoran Clay Member of the Tulare Formation and the lowermost forms the basal zone of the Tulare.

Studies by R. J. Janda indicate that water-laid rhyolitic ash exposed near Friant, on the east side of the San Joaquin Valley, is within the upper unit of the Pleistocene Turlock Lake Formation of Davis and Hall (1959), an alluvial-fan deposit of pre-Tahoe age, and that the ash is correlative with the lacustrine Corcoran Clay Member of the Tulare Formation of Pliocene and Pleistocene(?) age. The Corcoran is a useful marker horizon that has been identified beneath a large part of the San Joaquin Valley on the basis of electric logs. Examination of core from drill holes near Madera shows that ash petrographically identical to that near Friant forms a 6-inch-thick layer in the Corcoran and occurs as reworked ash in clastic deposits overlying the clay; shards of similar ash were identified in specimens of the clay from outcrops on the west side of the valley near Los Banos. G. B. Dalrymple reports that sanidine crystals from pumice pebbles in the upper part of the ash near Friant yield a potassium-argon age of 580,000 years.

J. H. Green, mapping the late Tertiary and Quaternary deposits along the west border of the San Joaquin Valley, was able to separate the Jacalitos and Etchegoin Formations (Pliocene) as far north as Arroyo Ciervo, 25 miles north of Coalinga. Earlier workers had not differentiated these units north of the Coalinga district.

Marine strata of late Pliocene age were recognized for the first time along the eastern side of the San Joaquin Valley by R. L. Klausing and K. E. Lohman in core from a drill hole near Richgrove, about 30 miles north of Bakersfield. Siltstone beds at a depth of 1,100 to 1,600 feet below land surface, which were formerly assigned to the Etchegoin and Chanac Formations, yield an extensive diatom assemblage similar to that of the Pliocene San Joaquin Formation in the Kettleman Hills.

## ALASKA

Figure 3 is an index map of Alaska showing the boundaries of the regions referred to in the following summary of scientific and economic findings of recent geologic and geophysical studies.

### Northern Alaska

A small but significant group of fossil plants collected by I. L. Tailleur from the coal section underlying the Lisburne Group near Cape Dyer, Alaska, are of the *Adiantites-Lepidodendropsis* complex, according to S. H. Mamay, and clearly indicate early Mississippian age. The assemblage is tentatively referred to floral zone 2 of Read and Mamay [58] and is the northernmost-known extension of the Mississippian flora. J. T. Dutro, Jr., identified invertebrates of Late Mississippian age near the base of the Lisburne Group. Because the carbonate-paralic contact seems to be at a somewhat lower level in the Lower Mississippian at Cape Thompson, 35 miles south, a northerly transgression of marine conditions during Early Mississippian time is inferred by Tailleur.

Also, according to Tailleur, analysis of seven channel samples representative of this coal section shows that the coal is high-rank bituminous in grade, comparable in composition to steam coals mined in the conterminous United States.

Twenty-five collections containing a total of 19 species of fossil fresh-water and land-dwelling mollusks were made by D. S. McCulloch from deposits of late Illinoian to Recent age in the Kotzebue Sound area of western Alaska. The faunas are all composed of species now living in Alaska; they appear to contain more individuals and species during warm periods (Sangamon and a post-Wisconsin thaw period) than during glacial intervals; and they show shifts in distribution of species with changing ecological conditions.

McCulloch also collected a fossile marine mollusk fauna containing more than 60 species from sediments of a marine delta that crops out on the Baldwin Peninsula and north shore of Hotham Inlet in the Kotzebue Sound area. These deltaic sediments are stratigraphically well dated because they lie directly under, and were deformed by, Illinoian till. Their age is, therefore, pre-Illinoian and probably Yarmouth. However, F. Stearns MacNeil correlates the fauna with faunas of the Boreal Transgression in Chukotsk, to which the Russians assign a Sangamon age. Studies by Hopkins also showed that during the several times in the Pleistocene Epoch when sea level was lowered enough to bring a

[58] Read, C. B., and Mamay, S. H., 1960, Upper Paleozoic floral zones of the United States: Art. 176 *in* U.S. Geol. Survey Prof. Paper 400-B, p. B381-B383.

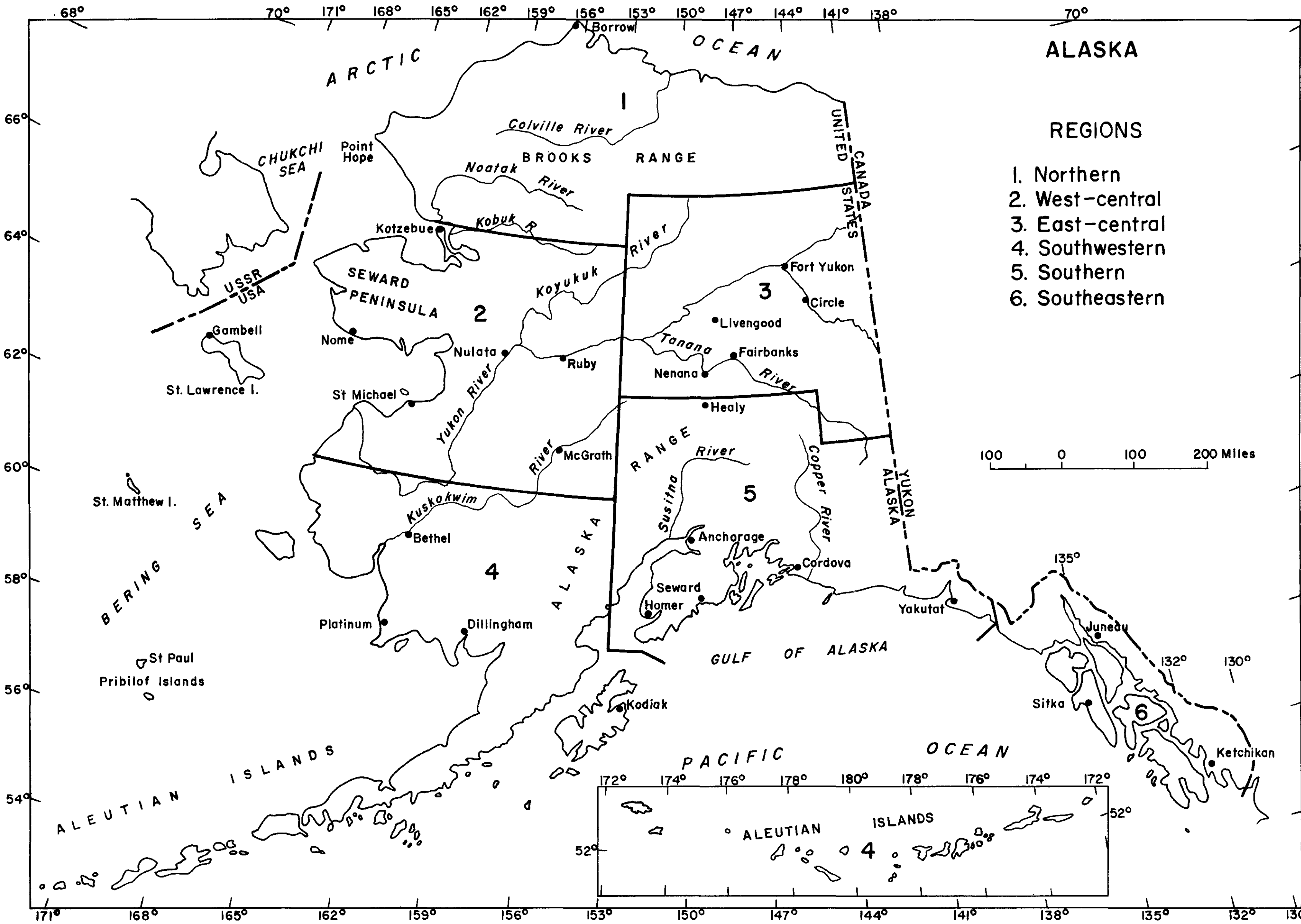


Figure 3.—Index map of Alaska, showing boundaries of regions referred to on accompanying pages.

land connection between Alaska and Siberia into existence, the resulting land bridge had permafrost and a severe climate and supported only tundra vegetation.

### West-central Alaska

According to Helen Duncan, the identification of the unusual fossil *Aphrosalpinx*, regarded as an archaeocyathid by Russian specialists, points to the presence of Silurian rocks in the McGrath region. This fossil has been recorded from a number of localities in the central and northern Ural Mountains where the enclosing strata are considered to be of Ludlow age. Middle Ordovician ostracodes, some belonging to European genera not common elsewhere in North America, have also been identified by Jean Berdan from samples taken in the McGrath region.

Geologic mapping by J. M. Hoare and W. H. Condon in western Alaska reveals that laumontite is developed on a regional scale in sandstones of middle Cretaceous age in the Koyukuk geosyncline. Laumontitized strata are exposed over an area of 2,000 to 2,500 square miles. The altered strata, which are probably a few thousand feet thick, may be recognized in the field by their mottled or speckled appearance. Field relations indicate that the laumontite formed under diagenetic conditions at the expense of volcanic ash.

Mapping by W. W. Patton, Jr., and A. R. Tagg demonstrated that a marked difference in the character of the Koyukuk basin occurs across the Kaltag fault. North of the fault, which transects the basin between Kaltag and Unalakleet, the sedimentary rocks of the Cretaceous basin are relatively free of igneous rocks. South of the fault, however, both volcanic and plutonic rocks are widespread. Three and perhaps four episodes of volcanism (Valanginian, Albian–Cenomanian, (?)Late Cretaceous–Tertiary, and Pleistocene) and at least one episode of plutonism (Valanginian–Albian(?)) were recognized. The abundance of igneous rock makes the petroleum possibilities of the basin south of the fault much less promising than north of the fault.

New information was gathered on the history of the Bering land bridge in the course of a paleomagnetic and Pleistocene stratigraphic study of the Pribilof Islands by D. M. Hopkins and A. V. Cox. The islands lie at the edge of the continental shelf in the southeastern Bering Sea. The investigation showed that St. Paul Island was built up above sea level by volcanic eruptions that took place entirely within the present normal polarity epoch ($N_1$). St. George Island is much older; only a few of its lava flows and cinder cones are as young as the last period when the earth's magnetic field was reversed (polarity epoch $R_1$), and the bulk of the island consists of lava flows erupted during the next previous normal and reversed polarity epochs ($N_2$ and $R_2$). The oldest recognized lava flows of the $R_2$ polarity epoch on St. George Island rest upon fossiliferous marine gravel. The gravel contains a fauna comparable to that from Submarine Beach at Nome and from the oldest part of the Gubik Formation of the Arctic Coastal Plain of Alaska, both of which are considered by Hopkins and F. S. MacNeil to be of earliest Pleistocene age, and both clearly were deposited after the present marine basins of the Bering and Chukchi Seas came into existence. Thus the first opening of a marine connection between the Pacific Ocean and the Arctic Ocean in the Bering Sea area took place at least as long ago as polarity-reversal epoch $R_2$.

### East-central Alaska

The rocks in eastern Survey Pass quadrangle are lithologically correlated by W. P. Brosgé and H. N. Reiser, with the Devonian and Devonian(?) sequence they established in the Chandalar quadrangle (see Prof. Paper 424–A p. A42). If this correlation is valid, they believe that the sequence of rocks that overlies the Skajit Limestone in the synclinorium in the northeastern Survey Pass and the northwestern Wiseman quadrangles can best be explained as a series of thrust plates that superimpose clastic rocks of approximately the same early Late Devonian age but of different facies.

Radiometric age analyses made for Bond Taber and D. M. Hopkins indicate that the relative ages of intrusive complexes in the Manley Hot Springs area are opposite to the age sequence assumed previously. Specimens from one of the bodies in the Roughtop Mountain intrusive complex have yielded a lead-alpha age of 90± 10 m.y. and a potassium-argon age of 90 m.y., indicating that the complex was intruded early in Late Cretaceous time; a specimen from the Hot Springs Dome granite body, 12 miles to the south, has yielded a potassium-argon age of 60 m.y., indicating that it was intruded near the beginning of Paleocene time.

E. E. Brabb and Mr. Churkin, Jr., mapped the Charley River quadrangle and have found a prolific fauna of probable Early Devonian age, the first of this age to be reported from Alaska, in a siliceous shale and chert formation in the McCann Hill area, north of Eagle. Some ostracodes in the collections, identified by Jean Berdan, belong to European genera not common elsewhere in North America. The formation also contains Silurian and Ordovician graptolites in its lower part and overlies Cambrian limestone, indicating that the early Paleozoic sequence is nearly complete. The siliceous shale and chert formation is near a much thicker carbonate sequence of possibly the same age, suggesting either abrupt facies change or major structural dislocation of facies.

Brabb and Churkin have used feldspar staining effectively in distinguishing coarse detrital rocks of similar appearance but different age. North of Tintina trench, potassium-bearing feldspar is common in rocks younger than middle Cretaceous but is absent in older rocks. Pollen studies by R. H. Tschudy in conjunction with the feldspar staining indicate that rocks of Late Cretaceous age, not previously recognized in the quadrangle, crop out along the Nation River and probably also along the Kandik River.

Helen L. Foster has found a previously undescribed carbonaceous sedimentary formation south of the West Fork of the Dennison River near the Taylor Highway, Alaska. The age of the formation is probably Late Cretaceous or Tertiary. Lithologically the formation is similar to rocks previously reported on the north side of the Tanana River near Wolf Lake.

In the Tok Basin, Alaska, Henry R. Schmoll has found evidence that a large lake existed at some time during the Pleistocene. The lake level was at least as high as 2,100 feet in elevation. Schmoll also traced the position of a previously unmapped fault between the Mentasta Pass area and the Little Tok Basin. This fault is probably a segment or branch of the Denali fault.

Compilation of geologic quadrangle maps of the Fairbanks A–2, A–3, A–4, and A–5, and the Healy D–2, D–3, and D–4 quadrangles by Clyde Wahrhaftig required correlating periglacial terraces on the Totatlanika River and Tatlanika Creek with the outwash terraces of the Nenana River described in Prof. Paper 293. When the correlations were made, longitudinal profiles of the streams and their terraces were constructed from topographic maps. Projected onto lines perpendicular to the range front, the profiles show that the streams and their terraces have markedly different slopes and heights. The present slopes of the streams bear an inverse relation to discharge, but the differences between the present stream gradients and the slopes of the terraces are in good agreement on all three streams for terraces of a given age. These differences in slope are presumably due to tilting of the range since the terraces were formed, and confirm Wahrhaftig's idea that the divergence in terrace slopes on the Nenana River is due to a northward tilting and uplift of the Alaska Range that was continuous throughout the Pleistocene.

The east-trending belt of sharp magnetic anomalies in the central part of the Tanana lowland, together with exposures of basement rocks in the Wood River Buttes, Clear Creek Butte, and the hills around Blair Lake, indicate to Gordon E. Andreason that the possible area of a sedimentary basin beneath the eastern part of the Tanana Flats is small. The Nenana Gravel probably pinches out northward either by thinning or by erosion between the Japan Hills and lat. 64°20′ N. Inasmuch as the Nenana is a continental formation and rests directly on schist, there is little room for an oil-bearing basin in the Tanana lowland east of long. 148° 15′ W. Nothing is known about the oil possibilities in the western part of the lowland, but they are reduced by the conclusions of this investigation.

David F. Barnes has nearly completed a regional gravity survey of a 50,000-square-mile area that includes the valleys of the Copper, Susitna, and Tanana Rivers. Several negative anomalies within this area suggest significant thicknesses of Tertiary sediments.

Radiocarbon dating by Meyer Rubin of fossiliferous unconsolidated sediment in the Manley Hot Springs area studied by D. M. Hopkins shows that a major cycle of gullying on slopes and redeposition in valleys took place in the Tofty placer district more than 50 years ago and less than 200 years ago. Fossils recording a tundra environment, studied by C. A. Repenning, were reworked from older loess on nearby slopes and redeposited in the valley bottom as a consequence of this recent cycle of gullying and alluviation. The gullying probably was a consequence of widespread forest fires that swept the western Yukon-Tanana upland during the earliest years of white occupation, late in the 19th century or early in the 20th century.

### Southwest Alaska

The outer Shumagin Islands, which jut 65 miles into the North Pacific from the western part of the Alaska Peninsula, were briefly studied by Arthur Grantz (Art. 27). They consist of slaty argillite and graywacke of late Mesozoic age and biotite granodiorite which has intruded them. These rocks are an extension of the belt of similar rocks in the Chugach Mountains and on Kodiak Island.

Biotite and hornblende from a sample of granodiorite collected from the Aleutian Range batholith were dated by the potassium-argon method. A $K^{40}/Ar^{40}$ age of 158 $\pm 8$ m.y. for the biotite was reported by G. J. Wasserburg, G. Donald Eberlein, and Marvin A. Lanphere (1–63). A replicate analysis of the biotite yielded an age of 160 $\pm 8$ m.y. The hornblende yielded a $K^{40}/Ar^{40}$ age of 168 $\pm 8$ m.y. These isotopic dates are consistent with stratigraphic evidence of an early Middle Jurassic (Bajocian) age for the intrusion according to R. L. Detterman and B. L. Reed.

The Tuxedni Formation is raised to group rank as a result of Detterman's studies in the Cook Inlet region (Art. 68). Names are given to formerly unnamed members and all members are raised to formation rank.

A fault believed responsible for a major earthquake in 1880 was discovered in the course of a study of Chirikof Island, Alaska, by G. W. Moore. Approximately 6 feet of vertical displacement is shown along the fault; and 40 square miles of the island and an unknown area of the sea floor were tilted. A resident living 3 miles from the fault recorded that the earthquake took place at 6:00 p.m., September 28, 1880. He wrote that the floor of his log cabin was twisted out of shape, deep cracks opened in the earth, stream drainage was disrupted, and the tide did not rise as high as it had before the shock. Aftershocks continued over a wide area of Alaska for about a month following the earthquake. Chirikof Island was subsequently abandoned until recent years, and the geology remained unknown until the present study.

### Southern Alaska

In the southern Wrangell Mountains, E. M. MacKevett, Jr., H. C. Berg, and George Plafker have discovered several previously unmapped Tertiary plutons. In one of these they found copper mineralization, the first report of Tertiary copper mineralization in the region of the famous Kennecott copper deposits which are in Triassic carbonate rocks. Their mapping also indicates that structural features, especially thrust faults, were more important in localizing the major copper deposits than previously realized. Fossils identified by N. J. Silberling show that the Nikolai Greenstone is probably late Middle or early Late Triassic in age, rather than its previous designation of Permian and Triassic(?).

Six potassium-argon ages of biotite and four lead-alpha ages of zircon indicate that the Kosina batholith of the eastern Talkeetna Mountains, Alaska, is about 160–165 million years old, Arthur Grantz reports (Art. 16). The batholith is post-Toarcian (Early Jurassic) and pre-Oxfordian (Late Jurassic) in age, and the sedimentary record suggests it was intruded very early in Middle Jurassic time. The data thus suggest a tie between the Toarcian-Oxfordian interval (and perhaps the Early–Middle Jurassic boundary) on the stratigraphic time scale and about 160–165 million years on the radioactivity time scale.

New collections of fossil plants made by Jack A. Wolfe and D. M. Hopkins from 50 localities in the Cook Inlet Basin and Matanuska Valley have led to a better understanding of the Tertiary stratigraphy of south-central Alaska. The Chickaloon Formation has yielded a rich subtropical flora of Paleocene age, similar to the Paleocene floras of Greenland and conterminous United States. The Tsadaka Formation, on the basis of its flora, is apparently a laterally equivalent facies of the oil- and gas-bearing Kenai Formation. The latter unit contains at least three distinct floral zones, ranging in age from late Oligocene through early Miocene.

Numerous diamicton units interbedded with stratified lacustrine sediments were noted by Oscar J. Ferrians, Jr., (Art. 91), within the unconsolidated deposits of Pleistocene age in the Copper River basin, Alaska. The character, the stratigraphic relations, and the distribution of these deposits indicate that many of the diamicton units were deposited in a lacustrine environment, and that turbidity currents and subaqueous mudflows were important as agents of deposition. Commonly the diamicton is till-like in character.

### Southeastern Alaska

Mapping on Baranof Island by R. A. Loney, D. A. Brew, L. J. P. Muffler, and J. S. Pomeroy has shown the island to consist mostly of generally northwest-striking highly deformed low-grade regionally metamorphosed rocks of probable Mesozoic and, in part, possible late Paleozoic age that are intruded by several granitic complexes with accompanying thermal metamorphism. Higher grade regionally metamorphosed rocks of the almandine amphibolite facies occur in two areas in the central and southern parts of the island. Several previously unknown small masses of peridotite and associated gabbro were mapped in a belt extending northwestward from the large dunite and pyroxenite intrusion at Red Bluff Bay on Baranof Island, but no potentially economic mineralization was found. A narrow parallel belt of tectonically intruded serpentinite bodies of varying sizes occurs a few miles to the west, and numerous individual bodies have been mapped. About 3½ miles of right-lateral separation is present along the north-northwest-striking Patterson Bay fault near where it is inferred to join the Chatham Strait–Lynn Canal lineament on the east side of Baranof Island. This displacement is probably strike slip in nature, and its sense is the same as that postulated for the lineament by Pierre St. Amand in 1957.

Joints, foliation, and faults influenced development of the ice-eroded deep fiords and valleys on Baranof Island (Art. 28). Northwest-trending linear topographic features parallel the generalized strike of the foliation, but are locally controlled by faults. Northeast-trending linear features parallel the generalized strike of several joint sets, but are locally influenced by faults.

### Mesozoic stratigraphy of Alaska

A review of the fossil pelecypods *Halobia* and *Monotis* by N. J. Silberling, based on collections made during 1962 and on specimens from Geological Survey reference collections, indicates that more than a dozen species of these genera can be distinguished in the Upper Triassic of Alaska and that in view of their widespread occurrence and restricted stratigraphic ranges, the po-

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tential value of these forms for dating and correlating these rocks has hitherto not been fully utilized.

## PUERTO RICO

The U.S. Geological Survey is cooperating with several governmental agencies of the Commonwealth of Puerto Rico in a study of the geology, mineral resources, and water resources of Puerto Rico and in the preparation and revision of topographic maps.

### Large faults near Barranquitas

The recently released geologic map of the Barranquitas quadrangle, Puerto Rico, by Reginald P. Briggs and Pedro A. Gelabert (1–62), describes a structurally complex area in the mountainous central part of Puerto Rico. Two types of large-scale movement were recognized along faults in this area. In the northern part, apparent stratigraphic displacement across an east-west zone of faulting possibly exceeds 2 kilometers; this apparent offset was interpreted as being in part the result of left-lateral strike-slip displacement of about 4 kilometers; more recent work suggests that the amount of strike-slip displacement may be greater, possibly as much as 20 kilometers. Within this transcurrent fault area is a large graben. Vertical displacement on a northwest-striking high-angle reverse fault may be more than 2½ kilometers. Displacements of such magnitudes have not been previously reported from Puerto Rico.

### Age of intrusion of Utuado batholith

The age of the intrusive rocks of the Utuado batholith in central Puerto Rico has been determined as 50 to 70 m.y. by T. W. Stern, using the lead-alpha method and as 62 to 68 m.y. by H. H. Thomas, R. V. Marvin, and F. Wathall using the potassium-argon method. These age determinations agree closely with the age of deformation in central Puerto Rico suggested by Mattson [59] on the basis of structural analysis and paleontology.

### Serpentine

The Geological Survey cooperated with the AMSOC (Mohole) Committee of the National Research Council in studies of a core hole drilled to a depth of 1,000 feet in one of several serpentine masses in extreme western Puerto Rico. P. H. Mattson, who logged the hole and studied the core, interprets the serpentine as being altered from augite harzburgite and from dunite. The rock is highly sheared and possesses a well-developed foliation inclined about 60°. Geophysical studies made by Andrew Griscom and R. W. Bromery show that gravity minimums and aeromagnetic maximums are associated with all the serpentine masses. Measurements of physical properties of the serpentine are in progress in order to compute from the geophysical data the shapes of these controversial bodies.

### Paleontology

The Cretaceous rocks of the Caribbean area have yielded few fossils save those that can be studied in cut and polished sections of limestone. Several localities in the Sabana Grande quadrangle of southwestern Puerto Rico have yielded silicified fossils. N. F. Sohl reports that on preliminary count the fossils from these localities have more than doubled the number of molluscan species known from the whole of the Caribbean Cretaceous. Among the fossils are a number representing genera not previously known from this hemisphere. One specimen of *Haliotis* represents only the second incontestable occurrence of the superfamily in pre-Tertiary rocks. The largest collection is assignable to the Maestrichtian stage. A smaller collection consisting of an erratic block of limestone from a volcanic breccia, collected by Peter Mattson, contained a fauna that compares with a similar silicified fauna from Guatemala that has been dated as early Cenomanian. Recent collecting by Sohl from elsewhere in Puerto Rico has resulted in the discovery of other species that are aiding in the correlation of the Puerto Rico Cretaceous sequence with that of the other Antillean islands and Central America. One such species is *Ostrea arizipensis* Böse, which has been found at several localities in the Sabana Grande and Orocovis quadrangles in Puerto Rico, in the higher Cretaceous beds in Cuba, in Jamaica, and in its type area in Mexico.

Samples of material from the Cibao Formation, northern Puerto Rico, have yielded an interesting fauna of larger Foraminifera dominated by numerous megalospheric specimens of *Lepidocyclina* (*Eulepidina*) *undosa* Cushman with multilocular embryonic chambers. Detailed analysis of these specimens by K. N. Sachs, Jr., and comparison with types of *L.* (*E.*) *undosa* suggests that the distinct embryonic apparati of the Puerto Rican specimens are the result of joining of a number of proloculi of megalospheric gamonts, with the subsequent formation of a single, common duteroloculus. Subsequent development of the individual is normal, producing adult structures the same as typical *L. undosa.* Joining of the proloculi rather than normal growth as discrete individuals is not considered normal, and is probably due to some external factor. Therefore, this feature should not be used as a criterion for the distinction of such subgenera as *Eulepidina* and *Pliolepidina.*

[59] Mattson, P. H., 1962, Unconformity between Cretaceous and Eocene rocks in central Puerto Rico [abs.]: Caribbean Geol. Conf., 3d, Program, Kingston, Jamaica, p. 29.

## ANTARCTICA

The Transantarctic Mountains (fig. 4), a 2,000-mile-long chain of mountains that crosses Antarctica from the Ross Sea to the Weddell Sea, has been the scene of ever-increasing geologic study since the International Geophysical Year. The U.S. Geological Survey began field work in this mountain system west of McMurdo Sound during the 1958–59 southern summer. The expansion of logistical capabilities by U.S. Navy Operation Deep Freeze in following years has allowed field studies in the remoter ranges in the interior. The Thiel Mountains were mapped in the 1960–61 and 1961–62 seasons and the southernmost parts of the Pensacola Mountains in the summer of 1962–63. In addition to studies in the Transantarctic Mountains, Survey geologists accompanied icebreaker expeditions along the coasts of the Bellingshausen Sea in 1960 and 1961 and on the 1959–60 Marie Byrd Land oversnow traverse. Antarctic studies are carried out in cooperation with the U.S. Antarctic Research Program of the National Science Foundation. Topographic mapping is discussed starting on page A192.

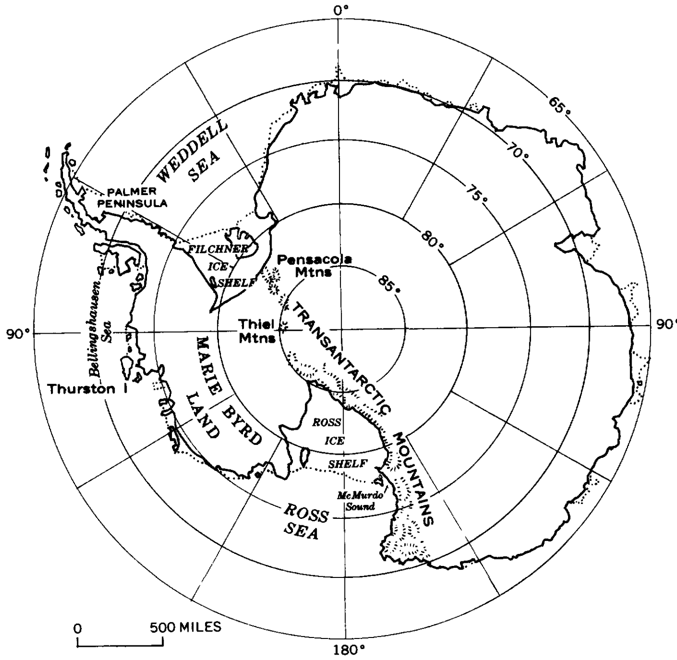


FIGURE 4.—Index map of Antarctica.

### Geology of the southern Pensacola Mountains

The Pensacola Mountains are a 250-by-50-mile, north-northeast-trending mountain group that lies along the southeast margin of the Filchner Ice Shelf. The two main northern ranges of this mountain group, the Neptune and Forrestal Ranges, are separated from the southern one, the Patuxent Mountains, by a 40-mile-wide polar outlet glacier that flows northwesterly into the ice shelf.

The Dufek Massif area at the northernmost end of the Neptune Range had been visited by an IGY traverse party in 1957–58 but little was known of the more remote southern parts of the Pensacola Mountains until they were photographed by U.S. Navy aircraft during the 1961–62 season. The geology of the Patuxent Mountains was studied in 1962–63 by R. D. Brown, J. H. Dover, A. B. Ford, and D. L. Schmidt; glaciology was studied by W. W. Boyd, Jr.; and geodetic control for mapping was obtained by T. E. Taylor of the Topographic Division of the Survey.

The most widespread rock unit in the Patuxent Mountains is a heterogeneous assemblage of unfossiliferous graywackes, siltstones, shales, and slates that has an areal extent of at least 2,500 square miles. The rocks are strongly folded and have well-developed mostly vertical axial plane cleavage throughout the area. Carbonate rocks at least 1,800 feet thick, which dip homoclinically toward the south, make up several nunataks in the western part of the mountains. Flat lying quartzites, sandstones, siltstones, carbonaceous beds, and several sills of diabase are probably correlative with the well-known Beacon Formation and associated basic sills which are widely distributed throughout East Antarctica.

### Glaciology and glacial geology of the southern Pensacola Mountains

Firn temperatures and densities were measured in several pits and bore holes, including one 30-meter-deep bore hole. Mean annual air temperature at 3,000-feet elevation in the Patuxent Mountains is about −28°C. Stake lines were surveyed across several glaciers for movement and accumulation studies. Young and fresh morainal debris is widely scattered throughout the area, and in addition there are local deposits of much older, deeply weathered tills. Erratics and glacial striations on nunataks show that the ice sheet has been at least 500 meters higher than at present.

### Geology of the Thiel Mountains

Cordierite-bearing, hypersthene-quartz monzonite porphyry is intruded by plutons of biotite granite and porphyritic biotite granite according to A. B. Ford and J. M. Aaron (1–62). Zircons in the quartz monzonite porphyry have been dated by the Larsen (lead-alpha) method at 620±70, and 530±60 million years (1–63). The charnockite-like nature of the rock suggests that the presumably Precambrian-age shield extends into West Antarctica from East Antarctica where charnockites are common. Radiometric age studies on these rocks and on the intrusive granites are being continued by S. S. Goldich and T. W. Stern (see p. A152).

Preliminary results suggest that granite emplacement occurred in early Paleozoic time.

### Glaciology and glacial geology of the Thiel Mountains

The continental climate of the area, 500 kilometers from the South Pole and 1100 kilometers from the ocean, is characterized by a mean annual temperature of −36°C. and an annual snow accumulation equivalent to 17 centimeters of water according to Bjorn G. Andersen (Art. 37). The flow of the continental ice sheet is very slow, probably less than 5 meters per year. High-level striae and erratics indicate that the ice was formerly at least 500 meters thicker than at present.

### Geologic reconnaissance of the Eights Coast

Laboratory study by A. A. Drake, Jr., of specimens collected during the United States 1961 icebreaker expedition to the Bellingshausen Sea, and collected from Thurston Island in 1960 [60] confirms the petrologic continuity of a body of batholithic dimensions. This batholith, although composite, is predominantly quartz diorite and has granodiorite and adamellite phases. These rocks are petrochemically dissimilar to those of known Andean age from the Palmer Peninsula.

[60] Craddock, Campbell, and Hubbard, H. A., 1961, Preliminary geologic report on the 1960 U.S. expedition to Bellingshausen Sea: Science, v. 133, no. 3456, p. 886–887.

The metamorphic rock found near lat 72°35′37″ S., long 95°07′00″ W. was found to be a leucocratic augite norite that has been intruded and metamorphosed by the quartz diorite.

Pink fine- to medium-grained granitic rock was found in float at three places along the Eights Coast, east of Thurston Island. This rock ranges in composition from granodiorite to granite and is characterized by abundant myrmekite. One specimen contains an inclusion of white quartz diorite typical of the Eights Coast. The pink granitic rock is remarkably similar to a specimen, furnished by Martin Halpern of the University of Wisconsin, of the typical plutonic rock at Gonzalez Videla, the Chilean base on Palmer Peninsula. This suggests that Andean plutonic activity may have extended to the Eights Coast region.

### Coal studies

Prolonged exposure of coal to extremely dry atmosphere, high wind, and low temperature commonly results in unusually high oxygen and varying moisture content. Coal samples from the Ohio Range of the Horlick Mountains (about 75 miles west of the Thiel Mountains) have been found by James M. Schopf at the Survey's Coal Laboratory in Columbus, Ohio, to be less oxidized at a depth of 20 feet than at the surface.

# INVESTIGATIONS IN OTHER COUNTRIES

United States scientific and technical assistance to other countries in the fields of geology and hydrology has been carried out for the past two decades by the U.S. Geological Survey, under the auspices of the Agency for International Development of the U.S. Department of State, and of other national and international agencies.

Of primary importance to such work are the mutual benefits derived from close professional relationships developed between the Geological Survey and its counterpart organizations throughout the world's earth-science community. These relationships among scientists and engineers, and among the respective institutions, facilitate the growth of the science, particularly with respect to economic geology and hydrology.

Any nation that wishes to utilize its natural resources effectively must develop its own cadre of competent, well-trained, and experienced earth scientists and engineers. To this end, most projects described here include scientific and technical training during the course of the cooperative mineral and water investigations.

In response to requests for aid expressed by other governments, the Geological Survey extended assistance to 20 countries during Fiscal Year 1963 by sending 90 specialists to those countries. In addition, 120 young geologists and engineers were brought to the United States for supplementary academic work in American universities, and for on-the-job training in water and mineral investigations and in photogrammetric and topographic mapping techniques.

Although the advisory and training activities are of major significance, they in themselves do not yield new geologic information and are not described here (see p. A263–A290 for a list of the activities). Some of the new information from cooperative field studies abroad is here summarized with emphasis on items of broad scientific and economic interest.

## AFGHANISTAN

### Surface-water studies in the Helmand River basin

A recent analysis of surface-water data in Afghanistan by Robert H. Brigham has led the Government of Afghanistan to adopt a schedule for operating the dams in the upper Helmand River basin to insure adequate flow for irrigation in downstream reaches, and indirectly for use in neighboring Iran. Streamflow in the Helmand valley dropped to the lowest of record in late 1962, and demonstrated to both Afghanistan and Iran the benefits of proper regulation of flow in the international Helmand River.

## BOLIVIA

### Engineering geology and mineral investigations

Ernest Dobrovolny's report (1–62) on the geology of La Paz valley supplies the construction engineer with new basic data about ground conditions which will greatly aid future city planning and development. Two special-purpose maps resulted from the detailed investigations of two sites where specific problems exist. The special-purpose map of the ground conditions interprets the geologic map in terms of foundation conditions, topography, hydrology, and lithology; it also indicates the kinds of problems that exist and suggests control measures to decrease hazards in urban construction. The special-purpose map of the ground-water conditions supplies data about permeability, physiography, and topography, and about chemical composition and sources of ground water. Detailed investigations furnish data about critical landslide areas and fluctuating ground-water levels in the central part of La Paz.

### Mineral investigations and mapping project

The National Department of Geology, with the financial assistance of the Agency for International Development as part of the Alliance for Progress, has become a key organization in the economic development of Bolivia. In 1962, 15 young Bolivian geologists of the department, under the supervision of Dr. Stanislav Kriz, an American geologist contracted by AID, and two U.S. Geological Survey geologists have completed geologic maps of 23,000 square kilometers on 1:50,000 planimetric base maps compiled from aerial photography, using existing triangulation. The maps are being used for several mineral exploration projects jointly supported by international development agencies such as the United Nations Special Fund, Agency for International Development, Inter-American Bank of Development, and by the Bolivian Government.

## BRAZIL

### Iron and manganese

After 16 years of active field study, the investigation of the iron and manganese deposits of the Quadrilátero Ferrífero, State of Minas Gerais, Brazil, is completed. The project was conducted in cooperation with the Department of Mineral Production of the Brazilian Ministry of Mines and Energy. About 7,000 square kilometers were mapped geologically on a scale of 1:25,000, embracing the whole range of the Precambrian section and the included intrusive rocks. This study will result in 16 chapters of U.S. Geological Survey Professional Papers, including descriptions of regional geology, ore deposits, economic geology, and metamorphism of the area. Recent publications include 3 papers covering 6 quadrangles, by J. E. Gair (1–62), R. F. Johnson (1–62), and Dorr and Barbosa.[61]

### Ground-water provinces

As a result of a recent hydrogeologic reconnaissance of Brazil for the Agency for International Development, Robert Schneider (2–62) subdivided the country into seven ground-water provinces based on the regional distribution of the dominant geologic units and their water-bearing characteristics. The three of the provinces, covering most of the country, are underlain by Precambrian crystalline rocks. The other coincide approximately with four extensive sedimentary basins and the narrow coastal plain.

Because of the widespread distribution of crystalline rocks of low permeability, it is difficult in many areas to develop adequate ground-water supplies. Problems include the relative deficiency of rainfall in northeast Brazil and the occurrence of mineralized water in the crystalline rocks of parts of this region. A potential problem is the excessive lowering of water levels and interfence among wells in the area of the city of São Paulo.

## CHILE

### Economic geology and sedimentation

The metallogenetic map of Chile, scale 1:500,000, published by the Institute of Geological Investigations, was compiled by Carlos Ruiz F., Soloman Boronovsky, and George E. Ericksen. The map shows the principal ore deposits of Chile on a simplified geologic base map and supplies new information to aid in mineral-exploration programs.

In Aconcagua province, Chile, W. D. Carter and Nelson Aliste, a colleague of the Institute, recognized that several semiparallel paleochannels could guide exploration at the Guayacan mine, where copper sulfide ore bodies are contained in the vesicular tops of andesite-porphyry lava flows. The ore bodies and crests of the flows strike nearly due west and are separated by parallel, channel-like depressions filled with arkose that in places is weakly mineralized, and in other places is barren. The arkose grades upward into calcareous siltstone and limestone of marine origin that cap the crests of the flows. Over the crests of the flows the rocks are impregnated by primary sulfide minerals that replace the carbonates. Recognition of the irregular contact between volcanic and sedimentary rock has greatly facilitated mining and has encouraged further exploration at the Guayacan mine and other mines of the district.

Recent investigations by Kenneth Segerstrom and geologists of the Institute of Geological Investigations confirm that extensive "diamicton" deposits near Santiago at altitudes of 450–900 m above sea level are not till, as formerly believed, but are mudflows that have descended from the steep Andean mountain front to the east during Pleistocene and Recent time. Similar mudflow deposits of great extent and thickness are found in valleys in the Andes of central and northern Chile; one of them, 4 km long and as much as 30 m thick, was deposited as recently as April 18, 1959.

At the latitude of Santiago (30°30′ S.), morainal deposits are found in one valley as low as 1,670 m above sea level and in most major valleys above 2,000 m. The moraines and mudflows both have hummocky surfaces and are formed of material that is virtually unsorted and unbedded and that contains subrounded blocks as much as 2 m across. Moraines are found only in U-shaped valleys and cirques, but mudflows may be either in glaciated or unglaciated terrain. Criteria used to distinguish moraines from mudflows are: (1) the matrix of the morainal deposit is typically gray unweathered rock flour, whereas that of the mudflow is typically brown weathered material in various stages of chemical and mechanical disintegration; and (2) bedrock is generally fresh under the moraines, but is deeply weathered under the mudflows.

### Salt investigations in northern Chile

Under the auspices of the United Nations Special Fund, George E. Ericksen completed a field study and a comprehensive report on the geology of the salt deposits and the salt industry of northern Chile.[62] This is the first comprehensive geologic study of the salt deposits of northern Chile, including nitrate deposits, and this new information is an aid to the understanding

[61] Dorr, J. V. N., II, and Barbosa, A. L. M., 1963, Geology and ore deposits of the Itabira district, Minas Geraes, Brazil: U.S. Geol. Survey Prof. Paper 341–C.

[62] Ericksen, G. E., 1963, Geology of the salt deposits and the salt industry of northern Chile: New York, United Nations Special Fund, 164 p., 36 figs., 32 tables.

of origin and mode of emplacement of salt. It has been confirmed that part of the salt is of volcanic origin. Three types of salt deposits are recognized: caliche nitrate deposits from which sodium and potassium nitrate, iodine, and boric acid are being recovered; salars or salt pans which are mined for sodium chloride, sodium sulfate, and borates; and secondary sulfate deposits that have been mined for aluminum sulfate.

### Ground-water investigations

A series of ground-water investigations begun in 1955 were completed in 1962 by R. J. Dingman (1–62, 1–63, 2–63) and W. W. Doyel. Hydrogeologic studies were completed in the Pica, San Pedro de Atacama, and Santiago areas. Geologic mapping at a scale of 1:50,000 in support of the hydrogeologic work was completed for six 15-minute quadrangles: Pica, Matilla, Alca, Chacarilla, Tulor, and San Pedro.

The Pica investigation indicated that there was little likelihood of developing additional water supplies, but that the available ground-water supply could be used more effectively. In the San Pedro de Atacama investigation, test drilling resulted in the discovery of an artesian aquifer that yields water readily to wells.

At Santiago, where about half of the municipal supply for a city of 3 million people is furnished by ground water, test drilling indicated a new deeper artesian aquifer which will augment the city's supply.

## EGYPT

### Corrosion of well casings in the Western Desert

In a study of corrosion responsible for serious deterioration of steel casings and screens in artesian wells in Dakhla and Kharga Oases of the Western Desert, F. E. Clarke found conditions conducive to external corrosion at all depths studied. Measurement of pH, oxidation-reduction potentials, and other water-quality factors showed that the desert ground waters belong to thermodynamic domains where ferric oxide protective films dissolve readily, leaving bare steel exposed to attack by free carbon dioxide and sulfide, which are prevalent under the conditions that prevail in the aquifers. Electrical potential measurements in well casings confirmed that the steel surfaces are within Pourbaix's "dangerous triangle" and that corrosion is inevitable.

Cathodic protection is not feasible in such remote desert areas, and organic coatings will not provide adequate protection without supplemental cathodic treatment to compensate for coating flaws. The least expensive chemical treatment of bottom-hole water would be too costly for the flows involved. Studies are continuing to devise economical and practical materials and designs for new wells.

## INDONESIA

### Concretionary bauxite deposits

Preliminary field investigations show that deposits of concretionary bauxite are widespread, but that these deposits are smaller and of poorer quality than those now being mined. However, these newly found deposits contain an appreciable quantity of ore having about 45 percent alumina and less than 10 percent silica. A close correlation was found between the kind of bedrock and the grade of concretionary deposits. Concretionary deposits formed from syenitic rocks are of good quality. Those formed from volcanic rock or phyllite may be of good quality but tend to be high in iron content. Deposits associated with sandstone and shale tend to be thin and high in both silica and iron content. As medium to coarse quartz grains are not completely leached during weathering of the bedrock, deposits formed from granite or coarse sandstone are high in silica content. Other factors that influence the formation of concretionary deposits are altitude, topography, and possibly the relation to old drainage systems. Deposits now being mined are near sea level, whereas in the area studied, 50 km to the west, the best deposits are on the higher hills at altitudes of 60 to 80 m.

## ISRAEL

### Carbonate-rock aquifer of central Israel

In a geohydrologic investigation of a carbonate-rock aquifer, Cenomanian–Turonian in age, Robert Schneider observed that under natural conditions the ground-water temperature increases westward in the general direction of flow. Pumping has modified the temperature distribution locally by changing the flow pattern. The data suggest that mapping the temperature distribution may assist in determining the flow characteristics of carbonate-rock aquifers.

## LIBYA

### Minerals investigation and mapping

A project for evaluation of the mineral resources and mapping of Libya, under the guidance of G. H. Goudarzi, was started in 1954 and completed in 1962. The principal results of the project have been the publication by the Geological Survey of a new topographic base map (U.S. Geol. Survey, 49–62) at the scale 1:2,000,000 and the compilation of a manuscript geologic map of Libya at this scale which is being prepared for publication. A report on the geology and mineral resources of Libya is under preparation.

### New ground-water supply for Sirte

Recently completed hydrogeologic work by William Ogilbee has disclosed the presence of a fresh ground-water body in Miocene limestone in the vicinity of Qasr bu Hadi, inland from Sirte, in a region otherwise characterized by brackish or saline ground water. This fresh-water body is trapped on the south, upgradient side of a northwest-trending reverse fault and east of a small anticlinal flexure, and is apparently sustained and recharged by infiltration from seasonal runoff in the Wadi Tlal. When development of this water body by production wells is complete, a 20-km pipeline will deliver the much-needed fresh water to Sirte on the Mediterranean coast.

## NEPAL

### Potential hydroelectric development

Preliminary investigations of the water resources of Nepal by F. M. Veatch, Harry Hulsing, and Daniel E. Havelka indicate bountiful supplies of surface water of good quality. At least 12 large rivers originating in the high Himalayas or the Tibetan plateau have potential for extensive hydroelectric-power development. In addition, a large number of smaller streams are suitable for small power plants. Preliminary studies show that these rivers and streams not only have steep descents in relatively short horizontal distances but have high sustained flows. The flows are maintained not only by glacial water and snowmelt from the Himalayas and the plateau of Tibet but also by the rain of the southwest monsoon which begins in June and continues into September.

## PAKISTAN

The Mineral Exploration and Development Program of Pakistan is a joint undertaking of the U.S. Geological Survey, U.S. Bureau of Mines, U.S. Agency for International Development, and the Geological Survey of Pakistan.

### Chromite in the Hindubagh district

Preliminary mapping in selected chromite-mine areas at Hindubagh, West Pakistan, by R. van Vloten and T. W. Offield indicates that chromite bodies are localized at crests of folds in dunite of an alpine-type massif. Bearing and plunge of elongate crescentic, oval, or sigmoidal ore bodies can be determined by equal-area projection of planar and linear structural features. The configurations so far observed suggest that layers of granular refractory chromite within a layered mass of deformed ultramafic rock have been preserved on crests of folds and sheared out on limbs during flow folding which accompanied emplacement of the massif.

### Uranium sandstone deposits

Uranium-rich sandstone deposits near Rakhimunh village, Dera Ghazi Kahn district, that have been investigated by R. G. Schmidt and S. A. Asad of the Geological Survey of Pakistan and by geologists of the Pakistan Atomic Energy Commission, contain uranium and vanadium minerals in less than commercial quantities. The mineralization is in gray sandstone in the middle portion of the "Siwalik Group" rocks of Tertiary age. Uranium has been traced to a yellow-green mineral tentatively identified as metatyuyamunite. The presence of vanadium has been verified by microspectrochemical analysis. The uranium minerals may be present over a strike length of about 75 miles in the Siwalik rocks. They are also present in discontinuous lenses in sandstone and shale for a strike length of about 30 miles in the vicinity of Rakhimunh.

### Geologic reconnaissance in the Karakoram Range

Fieldwork and preliminary petrographic and heavy-mineral studies show that the metamorphism of the Gilgit-Nagar-Hispar area in the Karakoram Range of northern Kashmir is of lower grade biotite-to-garnet facies than that in the Hazara district farther south, and that the present tectonic structure of the area is almost entirely due to a single period of deformation related to the well-known "syntaxial bend" originally postulated by D. N. Wadia. The regional structure is marked by arcuate intrusions of granodiorite, which are almost all concentric about the "hub" of the "syntaxial bend." Mineralogic studies have shown that the area contains radioactive minerals as well as scheelite.

### Chagai district

R. G. Schmidt has completed mapping of the first 15-minute quadrangle in extreme western Pakistan near the border with Iran, resulting in new data about the geology and mineral reserves of this region.

The rocks in the area are sedimentary and metasedimentary, Cretaceous to Eocene in age, and overlain by younger rocks of undetermined age. A broad zone of contact metamorphism trends northward across the mapped area and is related to a group of small diorite stocks having the same trend. Many low-grade copper- and lead-bearing veins are located in faults in this zone. Metamorphosed volcanic conglomerate has been pyritized, locally containing as much as 15 percent pyrite along a belt 3 miles long and up to 2,000 feet wide. At places, limestones are replaced by as much as 20 percent pyrrhotite or are largely replaced by hematite. One diorite stock contains disseminated copper minerals.

### Coal deposits near Karachi

Under the guidance of R. L. Harbour, a Geological Survey of Pakistan drilling project in 1962 and 1963 established the presence of a large field of shallow, easy-to-mine coal at the crest of Lakhra anticline, 100 miles northeast of Karachi. Coal has been mined here at a single locality for many years, but the bed does not reach the surface, and before the test drilling the extent and number of coal beds were unknown. Drilling has shown that the mined seam extends about 5 miles from east to west across the anticline at depths of 80 to 250 feet, and 6 miles from north to south. As many as 3 discontinous lenticular coal beds were found below the mined seam. Reserves proved by the drilling are about 13 million long tons, and indicated and inferred reserves probably are between 50 and 100 million long tons as of February 1963.

#### Permian–Triassic boundary, Salt Range, West Pakistan

The Salt Range of West Pakistan has long been known as one of the few areas in the world where marine rocks of latest Permian age (*Cyclolobus* zone) are conformably overlain by marine rocks of earliest Triassic age (*Ophiceras* zone). However, almost nothing has been known about lithology, faunal distribution, and paleoecology of this important interval. Field studies carried out in the winter of 1961–62 by Curt Teichert, and by Bernard Kummel of the Museum of Comparative Zoology, Harvard University, show that the widely discussed faunal break between the Permian and Triassic Systems in this area is accompanied by a distinct lithofacies change. The studies were sponsored by the Agency for International Development and the National Science Foundation in cooperation with the Geological Survey of Pakistan.

The uppermost lithologic unit of the Permian System is the "Upper Productus Limestone" of Waagen, which consists of 220 to 280 feet of calcareous sandstone and sandy limestone containing a rich fauna of bryozoans, brachiopods, gastropods (especially bellerophontids), and the scaphopod *Plagioglypta.* More subordinate are Foraminifera, corals, pelecypods, nautiloids, and importantly, ammonoids, including the zone fossil *Cyclolobus oldhami* (Waagen). In most places the top of the "Upper Productus limestone" is formed by a few feet of usually unfossiliferous, only slightly calcareous sandstone.

In the entire area under investigation, which includes part of the trans-Indus Sughar Range, the "Upper Productus limestone" is overlain by a medium to coarsely crystalline dolomite unit, varying in thickness from 2½ to about 10 feet and containing the important zone fossil *Ophiceras connectens* Schindewolf, as well as some other ophiceratids, scattered shells of inarticulate and rhynchonellid brachiopods, pectinids, and occasional fish remains. In most places the dolomite contains many small unidentifiable echinoderm plates. Well-preserved cidaroid spines possibly represent the species *Miocidaris pakistanensis* Linck. The dolomite underlies the classic "Lower Ceratite limestone" of Waagen, which contains a rich and abundant ammonite fauna representative of the "Gyronitan" assemblage of Spath. Presence of benthonic echinoids and brachiopods in the basal Triassic dolomite is evidence that this rock was formed from an originally calcareous sediment that was laid down under conditions of fairly normal salinity.

The reasons for the intensive dolomitization of this thin unit at the base of the Triassic sequence are not fully understood. Relative coarseness and occasional porosity of the rock suggest late rather than early diagenetic processes, but the stratigraphic persistence of the unit, which is sandwiched between several hundred feet of nondolomitic limestone, sandstone, and shale suggests a very early diagenetic or penecontemporaneous dolomitization of the original sediment. Petrologic studies now under way may clarify the environmental significance of this basal dolomite unit.

#### Water-logging and salinity control in the Punjab region

Hydrologic investigations, in progress since 1953, by a Geological Survey team headed by David W. Greenman in West Pakistan indicate that the Punjab region is underlain by a vast and productive ground-water reservoir which has major potential for regulating and improving the management of the water supply. Drainage and salinity control by pumping from networks of tube wells are hydrologically feasible and, in fact, may be the only solution to the problem of sustained irrigated agriculture in the Punjab. Tube-well networks are the key feature of a massive land-reclamation and water-development program now underway. Under this program the ground-water reservoir will sustain withdrawals from thousands of tube wells for supplemental irrigation and will also provide carryover underground storage for runoff which cannot be fully controlled by surface reservoirs.

### PANAMA

#### New water law

A significant contribution to the water economy of Panama was made recently by Harold E. Thomas, who aided in the development of a code of water law, taking into account the natural hydrologic environment, the past legal precedents, the existing social and economic structure and probable future needs of the country. The proposed code is under review by legal authorities of the Panamanian Government.

### PHILIPPINES

#### Chromite resources survey

Geological mapping and exploration of the Zambales chromite area have shown that the composition of the chromite is reflected in the composition of the overlying gabbro. Part of the chromite-bearing zone overlain by olivine gabbro contains refractory-grade chromite; the metallurgical-grade chromite is overlain by norite. Compositional and size layering in all rock units, except dunite, crosses lithologic and chromite deposits at all angles. Layering in this type of chromite deposit cannot be used to predict the possible location of new deposits.

## SUDAN

### Ground water in Kordofan province

Recent work by Harry G. Rodis, and Wilson Iskander of the Geological Survey Department of Sudan, in central Kordofan province has demonstrated the presence of an extensive outlier of Nubian Sandstone largely buried by younger surficial deposits (Art. 49). This outlier contains a body of ground water of excellent chemical quality that is available for beneficial development in a region historically characterized by great water scarcity.

## SPAIN

### Pyrite deposits of Huelva province

A. R. Kinkel, Jr. (1–62), found that the massive sulfide deposits of the Huelva district, Spain, are associated with extrusive, rather than intrusive, rhyolite, as had long been thought. They are localized at a single stratigraphic zone consisting of coarse to fine pyroclastic material at the top of the flows and conformably underlying Lower Carboniferous shale. The ores are conformable with bedding, not with shear or fracture zones, and occur intermittently over a distance of more than 100 km. Restriction of ore to areas of coarse pyroclastic material suggests that mineralizing solutions may have been introduced to the basin through volcanic vents.

## THAILAND

### Mineral exploration and development

Sixteen reports, resulting from a joint project with the Royal Thai Department of Mines (RTDM), will be completed for publication by the RTDM by January 1964. This brings to an end 8 years of close collaboration aimed at diversification of the minerals industry and strengthening of the RTDM to a point where today it is one of the largest and best organized, trained, and equipped geological organizations in southeast Asia. Improvements include a modern minerals experimental center; mineralogic, chemical and petrographic laboratories; and a creditable geologic library.

The mining industry, at the outset of this work, was largely confined to the production of tin and tungsten for export. As the result of the Thai geologists' initiative, aided by Survey advice, guidance, and joint field and laboratory investigations, diversification for local consumption now includes new industries based on the following indigenous mineral commodities: (1) manganese (storage-battery plants); (2) gypsum and marl (cement plants); (3) antimony (alloys); (4) lignite (thermal power); (5) iron (small but expanding steel industry); and (6) clay minerals (expanded ceramics industry). The annual rate of production of these minerals has increased 20 fold from a value of about $80,000 in 1956 to about $1,600,000.

During fiscal year 1963, Louis S. Gardner, Charles L. Hummel, and Dwight E. Ward, working with their counterparts, completed all fieldwork within the joint projects and brought their reports to near completion. The cooperative USGS-United Nations Special Fund-RTDM project will continue this work in northeast Thailand through FY 1965.

## TUNISIA

### Ground-water appraisal of Téboula area

A study of hydrologic problems in central Tunisia by H. E. Thomas and L. C. Dutcher has disclosed an interesting ground-water dilemma in the Téboula area. Pumping at the current rate is depleting the ground-water reservoir, which contains stored water of better quality than that which replenishes the reservoir. Thus, even if the rate of withdrawal is reduced, the quality of water in some wells may deteriorate. They concluded that the fresh water should be developed by mining techniques allowing for some blending of waters to form a product of usable quality but depleting the reservoir at a rate sufficient to prevent excessive contamination.

## TURKEY

### Phosphate in southern Turkey

Application by R. P. Sheldon of the ideas, stated below, of genesis of phosphorite has led to the discovery of important phosphate deposits in southeastern Turkey. Phosphorite, according to these ideas, is deposited in areas of relative structural stability where deposition is slow and cold ocean currents well up into shallower water. These conditions were met in southeastern Turkey where the Mesozoic and Tertiary Tethys sea covered the Arabian craton and miogeosyncline to the north. Upwelling in the southern part of the Tethys sea is shown by the phosphorite province of the Mediterranean, which stretches from Morocco to Jordan. Field investigations of these ideas by Sheldon with Necip Tolun and Orhan Özdemir of the Mining Assistance Commission revealed deposits near Adiyaman, Kilis, and Diyabakir. Of particular help were gamma-ray logs made by oil companies operating in the area. The small amount of uranium in marine apatite causes a kick on the gamma-ray logs. The radioactive zones identified in well logs were examined in surface exposures and were found to be, in fact, due to the presence of apatite.

**Surface-water and sediment investigations**

In conjunction with surface-water studies, Leonard J. Snell reports that the upbuilding of flood plains and the seaward growth of deltaic deposits of Anatolian rivers emptying into the Aegean Sea was probably a major factor in the abandonment of many ancient Greek cities such as Miletus, Priene, Ephesus, Tarsus, and others. These cities which were flourishing seaports during the pre-Christian and early Christian eras now lie as much as 10 kilometers inland from the present shoreline.

# INVESTIGATIONS OF PRINCIPLES AND PROCESSES

## PALEONTOLOGY

Paleontological research plays a fundamental role in the U.S. Geological Survey's efforts, through its geologic mapping program, to reconstruct the course of earth history from primitive beginnings to present-day shape and farm. Paleontology has three main aspects—the study of plants, of vertebrate animals, and of animals without backbones. The first two relate principally to the nonmarine environment, both terrestrial and fresh water. The last is primarily means for studying the development of the ocean basins over the past 500 million years.

Three major kinds of investigations are underway: (1) taxonomic studies of particular biologic groups, involving morphologic, functional, population, ontogenetic, and phylogenetic analyses; (2) biostratigraphic studies delineating the distribution of fossil assemblages in space and time, including a restudy of long neglected classic areas; and (3) oceanographic studies documenting the environmental conditions of animal and plant groups that have fossil representatives, especially in the Tertiary rocks.

About 45 paleontologists, specialists in the taxonomy, evolution, and ecology of at least one major group of animals or plants, are actively engaged in research on fossils. Their main fields of interest and the parts of the geologic column covered by their studies are indicated in figure 5.

### *TAXONOMIC STUDIES*

Systematic descriptive studies of the interrelationships, evolutionary development, and paleoecological significance of fossils are fundamental to interpretive paleontology.

Contributions to the "Treatise on Invertebrate Paleontology," a comprehensive critical compendium sponsored by professional societies in this field, consist of basic revisions at the generic and suprageneric levels. Studies of this kind are of interest and importance to paleontologists the world over. Geological Survey paleontologists who have participated in this task, and the status of their contributions, are:

Jean M. Berdan and I. G. Sohn, sections in the ostracode volume (part Z); published.
Ellis L. Yochelson, coauthor, Paleozoic gastropods (part I); published.
Wilbert H. Hass, conodonts (part N); published.
R. C. Douglass, orbitoline Foraminifera (in part C); in press.
Mackenzie Gordon, Jr., and Curt Teichert, sections in the nautiloid cephalopod volume (part K); in press.
R. E. Grant, sections in the brachiopod volume (part H); in preparation.
Julia Gardner and L. W. Stephenson, sections in the gastropod volume (part J); in preparation.
A. R. Palmer, copepods (in part R); in preparation.
K. E. Lohman, diatoms (in part B); in preparation.

The life work of a great paleobotanist, Roland W. Brown (1–62), summarizes the known history, distribution, and stratigraphic significance of the earliest Tertiary flora in the mountain West. Apparently, more plant species crossed the Cretaceous-Tertiary boundary than was formerly supposed; no radical break in the floral sequence occurred. In addition, the early Eocene flora, with the exception of a species of the fern *Salvinia* and perhaps a few others, does not seem to be greatly different in general composition from that of the late Paleocene. The presence of palms and breadfruit on the one hand and of birches, hazels, maples, and ashes on the other suggests either that remains from different ecologic habitats mingled in a warm-temperate to temperate environment, or that some Paleocene species were adapted to environmental niches different from their comparable living descendants or relatives.

A fundamental synthesis of gastropod classification has been made by D. W. Taylor and N. F. Sohl (1–62). Annotations include references to the more important taxonomic groups and explanations of the ways in which divergent classifications have been reconciled. Gastropods are divided into the two subclasses Streptoneura and Euthyneura. Although the Streptoneura (4,218 genera and subgenera) is larger, it is divided into only 3 orders. The Euthyneura (3,106 genera and subgenera) is more diverse structurally and is divided into 14 orders. This outline should serve as a basis for all future work on the phylogenetic history of the gastropods.

A study by A. R. Palmer (1–62) of foreign Cambrian trilobites with American affinities shows that within the interval from the middle part of the Middle Cambrian to the middle part of the Upper Cambrian, reasonably precise intercontinental correlation can now be accomplished between the United States and north-

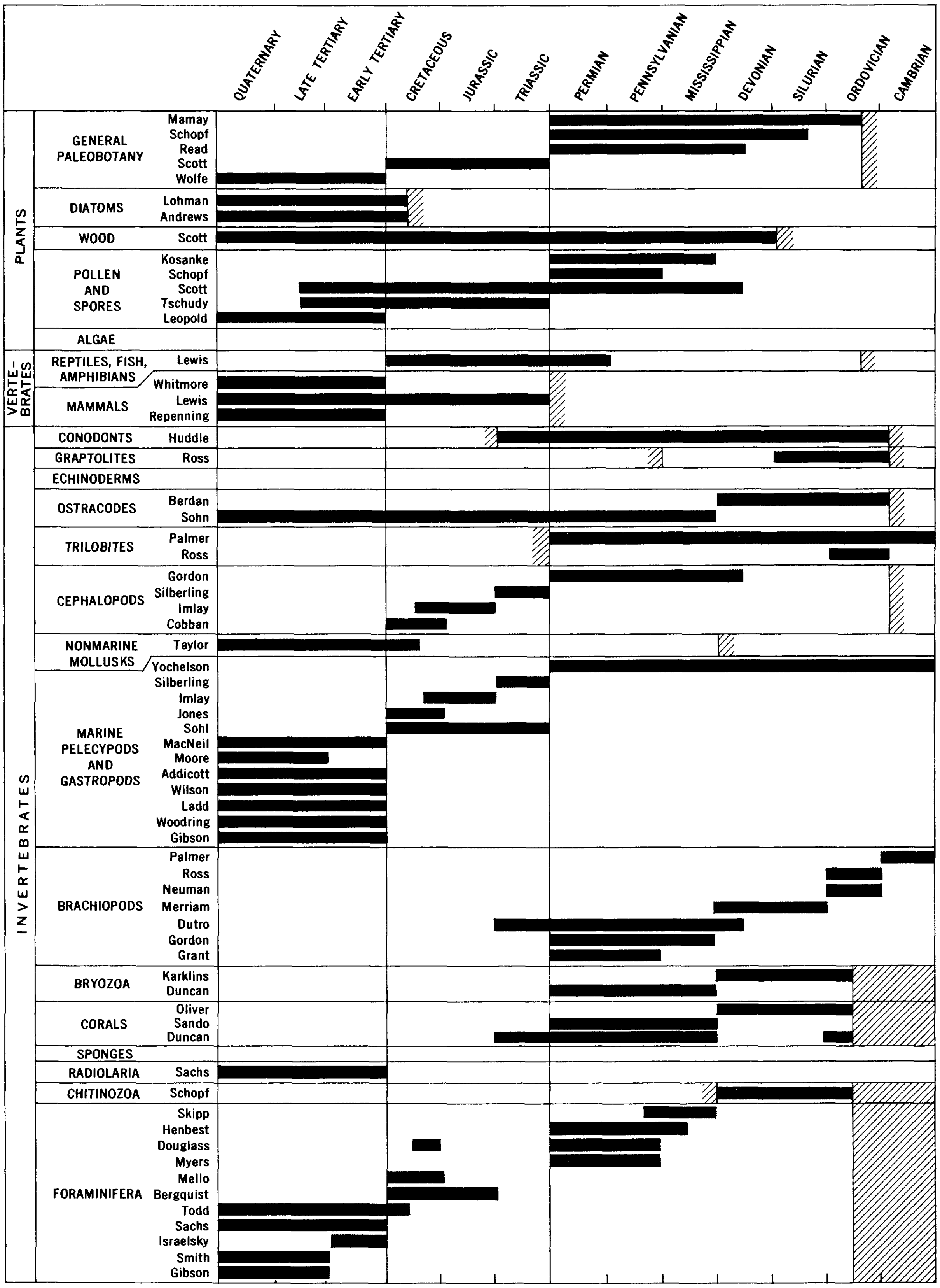


FIGURE 5.—Paleontologic responsibilities of professional personnel, showing the major biologic groups studied and their stratigraphic ranges. Diagonal lines indicate the presumed nonoccurrence of the particular fossil group.

eastern Siberia, northwestern Europe, and eastern Australia. Identical or closely comparable Upper Cambrian species assemblages from these areas are now known from at least three levels within the time span represented by the Dunderberg Formation of eastern Nevada.

The sequence of baculite cephalopods in the lower part of the Pierre Shale in the western interior was refined by Cobban (1–62) through a comprehensive analysis of species occurrences and ranges. The sequence from oldest to youngest appears to be: *Baculites obtusus* Meek, *B. maclearni* Landes, *B. asperiformis*, and *B. perplexus* Cobban.

A systematic description of the spores and sporelike microfossils of the Upper Devonian and Lower Mississippian rocks of Ohio by Marcia R. Winslow (1–62) emphasizes the stratigraphic ranges of the various floras and their possible paleoenvironmental significance.

The fossil assemblages of the Big Snowy Group, central Montana, have been described and their stratigraphic significance assessed by W. H. Easton.[63] Although the predominantly brachiopod faunules appear to be transitional between the Mississippian and Pennsylvanian, 53 of the 64 significant species indicate a dominant Mississippian aspect.

Silurian rugose corals from New York, Maine, and Quebec, described by W. A. Oliver, Jr., (3–62) shed new light on the methods of growth and stratigraphic occurrences of these important fossils. In a redescription of species from the Lockport Dolomite of New York, the methods of reproduction and interesting variation in *Diplophyllum caespitosum* are delineated. A thorough analysis of ontogeny and colony development in *Kodonophyllum corymbosum* is a part of the description of coral assemblages from eastern Quebec. In addition, interrelations among Maine and Quebec Silurian assemblages described by Oliver (1–62; 3–62) and Stumm (1–62) are suggested.

A revision by J. B. Reeside, Jr., of ammonites from the Cretaceous of New Jersey, originally described by Stuart Weller, provides modern terminology and new data on localities and stratigraphic significance of this group of cephalopods.[64]

Ellen Moore (1–62) has published a catalogue of Cenozoic type specimens described originally by Timothy Conrad and now preserved in the Academy of Natural Sciences of Philadelphia. This fine piece of paleontological detective work resulted in the recovery of 588 of about 900 types which many paleontologists had assumed were lost or destroyed.

A study of the gastropod family Turridae from the Miocene St. Marys Formation of Maryland by T. G. Gibson has shown that many characters previously used in the taxonomy of this family are of doubtful validity. However, the characters of the anal sinus and associated morphologic features seem to be significant for generic and specific differentiation within this group.

Anatomical studies of wood provide clues about the relation between fossil and living plant species. R. A. Scott, E. S. Barghoorn, and U. Prakash (1–62; and Prakash and others, 1–62) have described the woods of *Gingko*, *Robinia*, and *Gleditsia* from the Tertiary deposits of western North America. These studies not only show affinities with existing plants but also emphasize the extent of climatic and ecological change in the Rocky Mountain region during late Tertiary and Quaternary times.

Collections from the Permian Lueders Limestone, Baylor County, Tex., were found by S. H. Mamay to contain several specimens of a cupuliferous form of callipterid foliage. The cupules, or seed-containing structures, are borne terminally or lateromarginally on the pinnules and evidently represent an unorthodox type of female reproductive structure. The seed habit of the callipterids has been previously unknown, and this material warrants description (report in preparation) as a new genus, possibly a new family, of pteridosperms.

## BIOSTRATIGRAPHIC STUDIES

Interpretation of stratigraphic relations through analysis of assemblages of fossils is one of the major tasks of Survey paleontologists. Problems involving material collected by geologists with mapping projects provide a challenge to the paleontologist. Solution of these problems often requires further collecting and sometimes reorientation of the basic work of the paleontologist.

About a third of the activity of Survey paleontologists is in service work for other geologists. An indication of the geographic coverage of this work is shown in figure 6, and the distribution reflects the areas of intense geologic activity by the Survey.

A selected number of specific results during the past year only hints at the broad interests of Survey paleontologists and the wide scope of their stratigraphically significant investigations.

The regional affinities of coral species from the Redwall Limestone of northern Arizona show interesting relations with the coral faunas of contemporaneous

[63] Easton, W. H., 1962, Carboniferous formations and faunas of central Montana: U.S. Geol. Survey Prof. Paper 348, 126 p.

[64] Richards, H. G., and others, 1962, The Cretaceous fossils of New Jersey: New Jersey Geol. Survey Bull. 61, pt. 2 (paleont. ser.), p. 113–137.

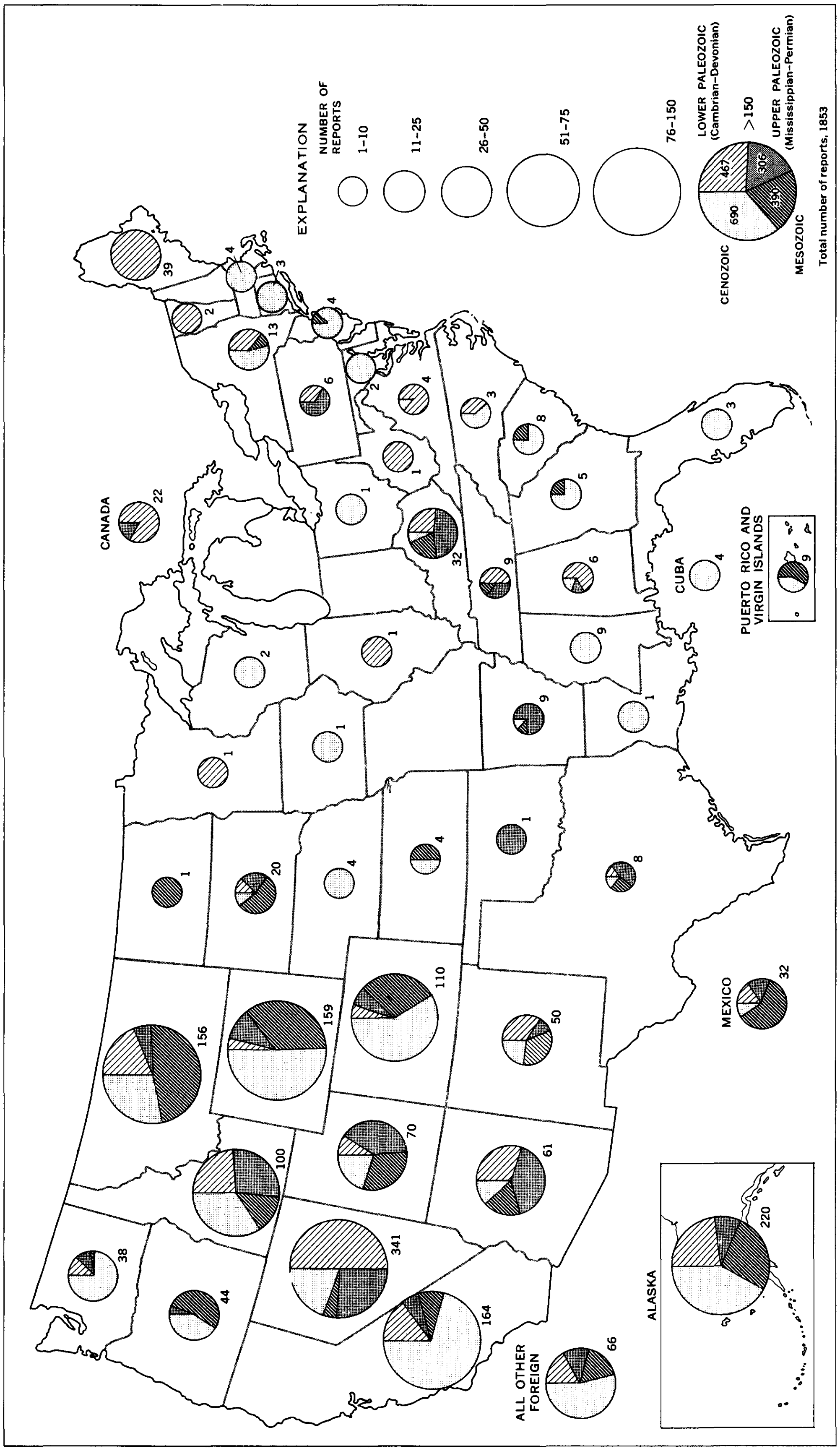


FIGURE 6.—Geographic and stratigraphic coverage of reports by Survey paleontologists on collections referred for examination, 1962–63.

strata in other areas of the United States, according to W. J. Sando. The Redwall Limestone contains only two species in common with the type Mississippian. Nine of the Redwall species show some affinities to Mississippi Valley forms, but eight species appear to represent exclusively Cordilleran elements. The Redwall corals show surprisingly few similarities to the faunas of the Escabrosa Limestone and Lake Valley Limestone of southeastern Arizona and southwestern New Mexico. The Escabrosa and Lake Valley faunas are strongly related to the type Mississipian. B. A. L. Skipp has examined collections from approximately 40 full and partial measured sections of Redwall Limestone (Mississipian) in the Grand Canyon and adjacent areas of northern Arizona, and has recognized a 6-fold foraminiferal zonation involving rocks of Early Mississippian (Kinderhook and Osage) to Late Mississippian (Meramec) age. The assemblage contains common representatives of the family Tournayellidae, previously reported only from the U.S.S.R., that may prove very useful for stratigraphic correlation in the Western States.

Two genera and two species of calcareous Foraminifera of Mississippian age, previously unrecognized in the United States, were identified by B. A. L. Skipp in the Diamond Peak Formation of Nevada. These forms, including *Endothyranopsis* Cummings 1955, *Haplophragmella* Rauser-Chernoussova and Reitlinger 1936, *Endothyra Omphalota* Rauser-Chernoussova and Reitlinger 1936, and *Endothyra* aff. *E. samarica* Rauser-Chernoussova 1948, are found associated with other Foraminifera typical of rocks of Chester age in the midcontinent region.

Type sections for the Pennsylvanian Morrow Series and new members of the Bloyd Formation in Washington County, Ark., are described by Lloyd Henbest (1–62; 2–62). This pinpoints, for the first time, sections that can be considered standards of reference for the lower Pennsylvanian rocks of the midcontinent region.

From the Snake River Canyon, Idaho, near the Oregon–Washington boundary, ammonites have been identified by Ralph W. Imlay as of early Oxfordian (early and late Jurassic) age. Previously, beds of this age had not been identified from the Pacific Coast region south of British Columbia. In addition, Imlay has identified early Jurassic ammonites from the Wallowa Mountains, northeast Oregon, establishing the presence of Jurassic rocks in this area for the first time.

As a result of a 10-day visit at the Geological Survey of Canada offices in Ottawa, Ontario, a much better correlation can be made now between Upper Cretaceous rocks of Canada and those of the conterminous United States. Dr. J. A. Jeletzky of the Geological Survey of Canada and W. A. Cobban examined numerous collections of fossils from the western interior of Canada and from the Arctic islands and agreed on many identifications. Interesting changes in the faunas as they are traced northward away from the international boundary include the coarseness of sculpture and the size of the species, especially among cephalopods.

In cooperation with the geologic mapping by David Hopkins and Clyde Wahrhaftig, a study of 7 pollen floras of late Tertiary age from Nome and from south-central Alaska has been completed by Estella B. Leopold. Five of the 7 floras are independently dated by fossil leaves or mollusks. The Pliocene rocks contain a modern Alaskan pollen assemblage, with an occasional pollen grain of hickory (*Carya*). The late Miocene flora is similar except that it contains a few pollen of the Asiatic ling nut (*Pterocarya*) and of the elm family. The late Oligocene or Miocene floras which do not show reworked Cretaceous pollen seem to have, in addition, pollen of podocarps (living *Podocarpus* is of warm-temperate and subtropical distribution) and *Liquidambar*. The Oligocene or Eocene floras contain, in addition to the forms mentioned above, pollen of holly (*Ilex*), linden (*Tilia*), and certain unnamed Tertiary forms that have also been recognized in Eocene and Oligocene floras of the northwestern states.

In July 1962, F. C. Whitmore and L. L. Ray joined with a field party from the University of Nebraska State Museum to dig for Pleistocene mammals at Big Bone, Lick, Ky., a site that is of historical as well as scientific importance because it was the first widely known vertebrate fossil locality in the Western Hemisphere. First reported by the French commander of Fort Niagara, who visited it in 1729, it was brought particularly to public attention in 1807 when President Thomas Jefferson sent Captain William Clark to the site to make a collection, part of which was sent to France, and part of which was deposited with the American Philosophical Society in Philadelphia. This collection, together with other specimens collected at Big Bone Lick in the early nineteenth century, has been important because it yielded the type specimens of at least 3, and possibly 5, species of mammals which were later found to constitute important elements of the Pleistocene fauna of the High Plains. These include an extinct muskox, the giant bison, a large mooselike deer, a tapir, and a ground sloth. Because these animals lived near the ice front, an accurate determination of their geologic age will, it is hoped, help to relate the history of ice-age faunas to glacial fluctuations. None of the previous collections at Big Bone Lick has been accompanied by records of the exact stratigraphic and geographic location of the specimens; thus it is impossible in most instances either to relate the fauna to the type of sediment or to date it accurately. This first season's collecting, therefore, was devoted to excavating the youngest of three bone-bearing zones under carefully controlled conditions. A pit 100 by 130 feet was dug and laid out in 10-foot squares for recording purposes. Although most of the 2,000 bones of the late ice-age mammals collected were from bison of about the size of the modern form, mastodon, horse, muskox, and deer bones were also found. In addition, wood samples were collected for carbon-14 dating.

W. W. Cobban has identified the ammonite *Hoplitoplacenticeras* from near the top of the Steele Shale in Carbon County, Wyo. This important find by E. N. Harshman provides for the first time a correlation of the western interior *Baculites asperiformis* Range Zone with the upper Campanian of the Late Cretaceous of western Europe (Art. 76).

F. Stearns MacNeil has completed a study of the evolution and distribution of the genus *Mya*, a clam with pelagic larvae. This is part of a study of trans-Arctic faunal migrations; it will be followed by a similar study of *Neptunea*, a genus whose larvae crawl rather than float. The following considerations lead to the conclusion that the Arctic Ocean came into being in middle Tertiary time: the known distribution of early Tertiary marine deposits, and of early Tertiary nonmarine and coal-bearing deposits in the high Arctic; the middle or late Miocene age of the oldest known marine Tertiary in the high Arctic; and the fact that the first Pacific species to appear in the Atlantic did so in late Miocene time. Since that time the Arctic appears to have been a regular avenue of migration between the Pacific and Atlantic Oceans.

John Huddle has described mixed conodont assemblages (Devonian and Ordovician) in the basal breccia of the Chattanooga Shale in the Flynn Creek cryptovolcanic structure of Tennessee. The age of the crater formation is apparently post-Richmond and pre-early Late Devonian (Art. 74).

Two new formations and seven new fossil zones are defined by J. T. Dutro and W. J. Sando [65] in the Mississippian sequence in the Chesterfield Range, Idaho. The new formations replace the old "Brazer Limestone" of southeast Idaho usage. Three Upper Mississippian coral zones extend previously published zonation in the northern Rockies. Four brachiopod zones augment the coral zonation.

During the summer of 1962, two faunal zones characteristic of the Upper Mississippian sequence in southeast Idaho and northern Utah were found by J. T. Dutro and W. J. Sando in post-Madison rocks of the Elkhorn Mountains, Mont., in the area mapped by M. R. Klepper. The *Striatifera* and *Caninia* Zones, described from the Chesterfield Range, Idaho, were identified in the middle limestone unit of the so-called "Amsden". In addition, *Caninia* Zone fossils were collected from unit 3 of McMannis' "Big Snowy" in the Bridger Range, Mont. The *Caninia* Zone had been identified previously from the upper "Big Snowy" of Hadley in the Gravelly Range, Mont., and from the upper "Amsden" of Rubey in the Bedford quadrangle, western Wyoming (Art. 23).

From a few outcrop samples on Great Swan Island in the Caribbean, collected by Harris Stewart of the U.S. Coast and Geodetic Survey, some planktonic Foraminifera were found that suggest deposition of the sedimentary rock at considerable depths, perhaps as great as several thousand fathoms. Ruth Todd and Doris Low found specimens of *Cassigerinella chipolensis* (Cushman and Ponton), a species that indicates an Oligocene or early Miocene age. The absence of *Orbulina universa* d'Orbigny in this pelagic facies supports its pre-late Miocene age.

Morphologic changes in the ostracode genus *Coryellina* are found by I. G. Sohn (2–62) to have stratigraphic significance. A small spine on the posterior surface of the valve is positioned higher along the posterior margin in progressively younger collections from Devonian, Carboniferous, and Permian rocks.

A detailed analysis of the stratigraphic distribution of fossils near the Pennsylvanian-Permian boundary in Kansas has led M. R. Mudge and E. L. Yochelson (2–62) to conclude that there is no definitive faunal evidence for an accurate placement of the systemic boundary. The commonly accepted boundary is at the top of the Brownville Limestone Member of the Wood Siding Formation. No change of this arbitrary boundary is anticipated by Mudge and Yochelson.

An analysis of the stratigraphic sequence and structural position of the pre-Tertiary rocks of northwestern Nevada, by N. J. Silberling and R. J. Roberts (1–62), has made possible a reconstruction of late Paleozoic and Mesozoic events in that region. The Antler orogeny in the Late Devonian and Mississippian obliterated the Cordilleran geosyncline of the early and middle Paleozoic. However, eugeosynclinal sedimentation continued west of the Antler orogenic belt until it, too, was terminated by the Sonoma orogeny in middle or Late Permian time. New marine invasions from the west resulted in deposition of a nearly continuous sequence of generally shallow-water marine volcanic and sedimentary rocks from Late Permian well into Jurassic time. Marine deposition was terminated by

[65] Dutro, J. T., and Sando, W. J., 1963, New Mississippian formations and faunal zones in the Chesterfield Range, Portneus quadrangle, southeast Idaho: Am. Assoc. Petroleum Geologists Bull. [In press]

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orogeny that started as early as late Early Jurassic and probably continued into the Cretaceous.

The Paleozoic history of the Antelope Valley area, Nevada, has been documented by the stratigraphic and paleontologic studies of C. W. Merriam (1–63). Major emphasis is placed on the Ordovician and Devonian Systems. Six Ordovician formations are described and their paleontologic content analyzed; this is particularly important because it is the type area of the Whiterock Stage of Cooper. Graptolite-bearing Ordovician beds (western facies) are correlated with the shelly carbonite facies. The Devonian discussion, and updating of Merriam's earlier work, is noteworthy for the introduction of evidence for a Helderberg age of the Rabbit Hill Limestone in the Monitor Range. The Nevada Formation and Devils Gate Limestone each contain four faunal zones; the significance of these zones in the age, correlation, and facies analysis of the Devonian strata is indicated.

A restudy of the biostratigraphy of the type Cincinnatian has been initiated in cooperation with the Kentucky, Indiana, and Ohio Geological Surveys, Ohio State University, and other interested scientists. The Kentucky–U.S. Geological Survey cooperative mapping project is stimulating further regional investigations. The coordination of stratigraphic and paleontologic data will fall to R. J. Ross. Cooperating geologists include R. B. Neuman, O. Karklins, John Pojeta, E. L. Yochelson, Jean Berdan, W. A. Oliver, E. R. Cressman, and F. A. Schilling of the U.S. Geological Survey; W. C. Sweet and M. P. Weiss of Ohio State University; E. R. Branson and M. O. Smith of the Kentucky Geological Survey, H. R. Gray of the Indiana Geological Survey, and R. J. Bernhagen and C. H. Summerson of the Ohio Geological Survey. It is hoped that other geologists well acquainted with the Upper Ordovician of this region will cooperate as the investigations progress.

Studies of Ordovician brachiopods from northern Maine by R. B. Neuman (Art. 30) reveal assemblages with strong British and Baltic affinities. Arenig equivalents are tuffs and tuffaceous sandstone in northern Penobscot County with orthids and clitambonitids including *Orthambonites*, *Platystrophia*, and *Tritoechia*. Llanvirn equivalents have not been seen. The Kennebec Formation of Boucot, 1961, in northern Somerset County, consisting of tuffs with *Valcourea*, represents the Llandeilo or lower Caradoc. A rich Caradocian assemblage occurs in tuffaceous mudstone and volcanic conglomerate in northern Aroostook County near Ashland. It contains such Baltic fossils as *Nicolella* cf. *N. actoniae* (Sowerby), *Chonetoidea*, and *Sampo* cf. *S. indentata* Spjeldnaes, forms not heretofore reported in North America. Ashgill brachiopods in mudstones and conglomerates in northern Penobscot County include *Retorsirostra*, *Sampo*, and *Schizophorella*, and mudstone of Ashgill age with different fossils occurs near Mapleton in Aroostook County.

## MARINE ECOLOGY AND PALEOECOLOGY

The relations of organisms to each other and to their physical environment provide basic data for the understanding of occurrences of fossils and their geologic significance. Reconstructing the past through a comprehension of the present is as fundamental to paleontology as it is to other phases of geologic investigations. The paleontologist must be zoologist, ecologist, and oceanographer as well as geologist, stratigrapher, and sedimentologist. Close ties between the Tertiary and the present are evident; many living genera and species are found as fossils in the not-too-old rocks of the Tertiary. In addition, distribution of land and sea masses and conditions of sedimentation did not differ greatly in the Tertiary. Some of the paleontologic results of the past year that reflect this wedding of the past and present are indicated below.

Separate findings by Druid Wilson and Frank Whitmore shed light on the Tertiary history of the Panama land bridge and its relation to the oceanic circulation in the Caribbean region. Whitmore's studies of Tertiary mammals indicate that the entire Isthmus of Panama was attached to North America in the early Miocene. Thus, it is probable that from the Paleocene to the Pliocene the strait separating the Americas was a north-south feature in what is now western Colombia. Wilson's analysis of Tertiary mollusks in Florida has confirmed the occurrence of *Anadara tuberculosa* (Sowerby), a living west coast Panamic clam, as a fossil in a late Pliocene (post-Caloosahatchee) molluscan assemblage. The Florida occurrence affirms a strong relation between Florida Tertiary and Recent west coast Panamic mollusks. This supports a date no earlier than late Pliocene for the closing of seaways between the Atlantic and Pacific Oceans.

From his study of large collections of fossils from the lacustrine facies of the Glenns Ferry Formation (late Pliocene and early Pleistocene of southwestern Idaho), Dwight W. Taylor reports (*in* Malde and Powers 1–62) that nearly all of the fresh-water mollusks (94 percent) belong to extinct species and that a large number belong to extinct genera. In degree of endemism, in the variety of species and genera, and in the great variety of individual forms, the Glenns Ferry mollusks are similar to those living in Lake Ohrid, Yugoslavia, and in Lakes Tanganyika and Nyassa, Africa. They also resemble fossil assemblages from the Pliocene deposits of the Pontian, Dacian, and Levantine basins of southeastern Europe.

The foraminiferal and molluscan content of 150 samples, together with sediment coarseness, was used by T. G. Gibson to interpret the paleoenvironment and paleogeography of the Miocene deposits of Maryland, Virginia, and North Carolina. All the formations are interpreted as being deposited in marine waters of less than 150 meters depth, and some units are of much shallower origin. The paleography of North Carolina, as indicated by the faunal evidence, includes an embayment in the central part of the coastal plain with relatively positive areas to the north and south. Geophysical evidence of the Cape Fear arch to the south and a relatively positive area south of Norfolk, Va., to the north, supports this conclusion. The Yorktown Formation is interpreted as the updip deposit on the northern and western sides of the embayment; the Duplin Marl is the downdip equivalent deposited in the deeper part of the embayment; and the Waccamaw Formation was deposited in the very shallow waters on top of the Cape Fear arch.

In a predominantly planktonic Foraminifera population, the benthonic fraction (although negligible in number of specimens) may be useful in paleoecologic interpretation. In a series of samples of deep-sea *Globigerina* ooze adjacent to an atoll, the number of benthonic species increases with nearness to the reef, according to Ruth Todd. Miss Todd also reports that fossil Foraminifera were found on the ocean bottom at several localities off the southeastern United States. Examination of glauconitic dolomitic limestone dredged from about 200 fathoms off the Georgia coast showed that it is an indurated *Globigerina* ooze, possibly as old as Miocene. Rare specimens of the Miocene species *Sphaeroidinella disjuncta* (Finlay), *Hofkerina semiornata* (Howchin), and *Globorotalia acostaensis* Blow or *G. opima* Bolli were found in rich *Globigerina* ooze bottom sediments on the Blake Plateaus, indicating a mixture of Miocene and Recent material. *Hofkerina semiornata*, found thus far only in the Miocene and Oligocene of Australia, has not been identified before in the Atlantic realm. Foraminifera in a series of short deep-sea cores from along the line of a slight depression behind the submarine feature known as Howell Hook in the Gulf of Mexico off southern Florida show no ecologic difference between the tops and bottoms of the cores. However, at the bottom (30.5 cm) of one of the cores a few Miocene species suggest that sediments of Miocene age may have been penetrated.

To obtain knowledge from modern pollen rain which will help to interpret fossil pollen assemblages, a study of seasonal modern pollen rain was begun in the Denver area by Estella B. Leopold. Four pollen trapping stations in west Denver were maintained during the summer months. Four standard rain gages were set up as pollen traps to obtain air-borne and rain-borne pollen and spores over given time intervals and to relate the sediment trapped to a definite catchment area. Total numbers of pollen deposited differed widely between sites; they are a function of wind speed. In contrast, the percentage composition of the summer's pollen rain differed relatively little from site to site. Some 12,000 pollen and spore grains per sq in. were deposited over the summer months at the ground station with the least wind, while only 4,000 grains per sq in. were obtained at the windy roof site. Internal percentages of various components differed somewhat among the four stations; these differences could not be explained by the different composition of local vegetation. Tree pollen represented 28 percent of the sample on the roof site, but only 18 percent on the ground below; this difference is thought to reflect vertical stratification of pollen types, a fact observed by others. Two other ground stations nearby yielded 33 percent and 27 percent tree pollen, respectively. The general succession in dominant pollen types was similar in timing and in general percentage composition at the 4 stations; from spring to fall it was: oak and *Cercocarpus*, pine and grass, chenopods, Compositae and *Artemisia*. Several Upper Cretaceous pollen grains fell into the trap in July; this led to the conclusion, after cautious checking, that pollen grains can be reworked by wind. These well-preserved grains represent extinct forms that characterize rocks of the Dakota Group, exposed a few miles west and upwind of the trapping site.

A joint study of late Miocene marine paleotemperatures in the southern San Joaquin basin, California, was made by W. O. Addicott and J. G. Vedder (Art. 77). New collections and previously published occurrences of shallow-water mollusks include several taxa suggestive of tropical marine climate. Earlier interpretations indicated a much cooler hydroclimate—warm temperate—based on a limited collection from one locality. Tropical and subtropical faunal elements in the southern San Joaquin basin suggest water temperatures warmer than those that existed to the west in the San Luis Obispo area during late Miocene time. The rather complex pattern of surface-water-temperature distribution in this part of California can be explained by the embayed coastline of the San Joaquin basin during the late Miocene; the area was protected from the apparently cooler water of the open ocean to the west by large insular or peninsular blocks.

The invertebrate fauna from marine terrace deposits at Cape Blanco on the southwestern coast of Oregon is the largest and one of the few known occurrences of late Pleistocene marine invertebrates between central California and British Columbia (lat 38°–49° N.). W. O. Addicott concludes that the assemblage inhabited a sandy bottom in shallow, offshore water at depths of 30 feet or greater. Extralimital northern species in the assemblage indicate a marine hydroclimate somewhat cooler than that which exists today at this latitude. Field relations at the nearby type locality of the Elk River Beds of Diller suggest that this name should be applied to gently deformed strata of probable late Pliocene age rather than to terrace deposits of late Pleistocene age.

Petrologic study by L. G. Henbest of the unusually good preservation of a few typical genera of late Paleozoic protozoans of the families Ammodiscidae and Cornuspiridae revealed the diagenetic history of the shells and provided a means of determining the nature of the original structure, which has been in controversy for many years. These long-neglected protozoans aid in determining the environment of formation of the ancient rocks containing their remains. Henbest suggests that dark, finely granular shell material of the late Paleozoic Cornuspiridae is a diagenetic end product of calcite with a high content of magnesium in solid solution and that a high magnesium content in Foraminifera shells is a result of symbiosis with algae.

E. L. Yochelson has made an analysis of the relations between rock type and associated fossils in the Permian Phosphoria basin of Idaho, Utah, Wyoming, and Montana. In the shelf facies of western Wyoming, the following regular sequence of fossil assemblages is observed from bottom to top: (1) large orbiculoid brachiopods and nuculoid pelecypods in a light-gray claystone, (2) large ramose bryozoan colonies together with *Derbyia* and *Spiriferina* in a dense bioclastic limestone, (3) a brachiopod assemblage (including *Neosprifer* and productoids) in a shaly limestone or calcareous shale, and (4) large spinose productoid brachiopods in calcareous shale. The succession of rock types and fossils, along with other physical factors, indicates marine transgression from the west with a change from firm to soft bottom conditions. To the east and south these shelf faunas change from brachiopod-bryozoan assemblages to molluscan assemblages with abundant *Plagioglypta*, interpreted as mudflat associations (Art. 34).

## MARINE GEOLOGY AND HYDROLOGY

During the past year the U.S. Geological Survey initiated a program in marine geology and hydrology. The new program consolidates and supports Survey studies of the features and processes of the oceans that relate to the geology and hydrology of the adjacent lands. Moreover, it forms an integral part of the new and rapidly expanding program of the U.S. Government to study the oceans and the ocean floor. New projects to investigate the composition, structure, geologic and hydrologic processes, and resources of marine areas will provide a better understanding of sedimentary rocks and other features that were formed in marine areas and subsequently were raised above sea level. Current emphasis is being placed on estuaries, bays, continental shelves, and other near-shore areas of the United States, its possessions, and trust territories.

## GEOLOGICAL AND GEOPHYSICAL STUDIES

Although a formal program in marine geology is new, the Geological Survey has long been active in studies of the oceans and ocean floors. In his "Data of Geochemistry", first published in 1908, and later successively revised and finally published as Geological Survey Bulletin 770 in 1924, F. W. Clarke presented one of the most comprehensive and authoritative reviews of the geochemistry of the oceans. Today, synthesis of geochemical data for the oceans and ocean floor continues and is being incorporated in the current sixth edition of "Data of Geochemistry" (see p. A146). Numerous studies have been made of samples from the ocean floor. In Professional Paper 196 (1940), W. H. Bradley and others described the petrology and paleontology of the first cores of more than a few inches in length collected from the deep-sea floor; some techniques devised by Bradley and his associates have become standard procedures and remain in use today. Professional Paper 260, "Bikini and Nearby Atolls," presents results of the most intensive oceanographic, geological, and geophysical investigation of a group of atolls and adjacent marine areas that has ever been undertaken. Results of other studies concerning oceanic features and processes by Survey geologists are contained in numerous bulletins, professional papers, and outside journals; papers such as "Marine Geology of Guam," by K. O. Emery (1–62), and the "Environment of Calcium Carbonate Deposition West of Andros Island, Bahamas," by P. E. Cloud (2–62), provide recent examples.

### Indian Ocean map

A map of the Indian Ocean showing the geology of bordering lands and the configuration of the ocean floor, by the late James F. Pepper and Mrs. Gail M. Everhart,[66] has been published as a contribution to the

[66] Pepper, J. F., and Everhart, G. M., 1963, The Indian Ocean—the geology of its bordering lands and the configuration of its floor: U.S. Geol. Survey Misc. Geol. Inv. Map I–380.

International Indian Ocean Expedition and the second ECAFE (United Nations Economic Commission for Asia and the Far East) Symposium on the Development of Petroleum Resources of Asia and the Far East. An accompanying text provides details on the geology of selected areas, and presents geologic information for the continental shelves and adjacent marine areas. The major purpose of the map and text, which has been compiled largely from published material, is to provide a geologic guide for future investigations of the Indian Ocean. Geologic cross sections of the near-shore marine areas show a number of structures comparable to those from which petroleum is produced in other parts of the world.

### Mohole project

Geological Survey scientists have continued studies of samples from the preliminary Mohole drilling site near Guadalupe Island, off the coast of Baja California, and are cooperating in projects related to future deep drill holes into the ocean floor. Allan Cox and R. R. Doell (1–62) have found that the average direction of remanent magnetization in basalt from Hole EM 7 at the Guadalupe site is reversed and that the natural magnetization is extremely stable and is probably thermoremanent magnetization formed during cooling of the basalt. George Keller and others are engaged in the development of instruments for measuring electric and magnetic currents within future deep drill holes on the ocean floor.

Dorothy Carroll has made mineralogic analyses of 7 samples of siliceous and calcareous oozes from cores obtained at the Guadalupe site. The oozes consisted of siliceous radiolarian remains, minerals of volcanic origin, and clay, and had ion-exchange capacities ranging from 6 to 20 milliequivalents per 100. The clay consisted of chlorite, mica, vermiculite, and montmorillonite; the ion-exchange capacities of the clays ranged from 24 to 36 milliequivalents per 100. The exchangeable cations were Ca>Na>K>Mg, although some of the calcium may have been liberated from calcite that was present in some separates.

### Studies of basalts from the ocean floor near Hawaii

During October 1962, a joint Geological Survey–Coast and Geodetic Survey team aboard the USCGS ship *Pioneer* cooperated in a dredging operation along the seaward extension of the east rift zone of Kilauea Volcano, Hawaii (Art. 40). The scientists obtained excellent photographs of fresh pillow basalts at depths of 10,800 and 14,400 feet and collected a suite of fresh lavas at depth intervals of about 1,000 feet to depths of 17,000 feet. Although pillow lavas are common among ancient uplifted submarine basalts, this is the first time that good examples have been photographed in the environment where they formed. James G. Moore and others at the Hawaiian Volcano Observatory have been studying the chemistry and petrology of the lavas recovered from the dredge. Preliminary studies of the petrography and other physical properties of the lavas show systematic increases in the density and decreases in vesicularity of the lavas with depth of extrusion.

In addition to work along the rift zone, photographs were taken and samples collected from depths of 5,200 to 6,200 feet on the summit of Bushnell Seamount, 75 miles southeast of Hawaii. Most photographs at this site show an old weathered surface, but pictures of one young, fresh lava flow with pillow structure were also obtained.

Twelve genera of corals, including 3 new species, have been identified in samples collected from depths of 5,000 to 6,000 feet on the seamount; sponges, echinoderms and other organisms within these samples are currently being studied.

### Gravity surveys of the Alaska Peninsula

D. R. Barnes has compiled results of gravity surveys on the Alaska Peninsula as part of a cooperative program to combine shoreline geophysical data with marine data obtained by the Coast and Geodetic Survey. Analyses of the 1962 data show a large gravity low on the northern side of the Alaska Peninsula, with lowest values near Port Mollar. The gravity low is caused by a thick sedimentary sequence contained in a basin that extends along the north side of the peninsula.

### Atlantic continental shelf and slope

During August 1962, the Geological Survey, in cooperation with the Woods Hole Oceanographic Institution, began a joint 5-year geological, hydrological, and geophysical investigation of the continental shelf and slope of the Atlantic coast of the United States (Emery and Schlee).[67] The joint project is under the direction of K. O. Emery of the Woods Hole Oceanographic Institution and J. S. Schlee of the Geological Survey. Laboratory facilities at Woods Hole have been prepared and equipped; the R/V *Gosnold* of the Woods Hole Oceanographic Institution has been converted and outfitted for marine geological studies; and existing pertinent data and samples have been assembled and studied. Following several short cruises to test equipment during April and May 1963, a month-long cruise for systematic collection of samples and data from the continental shelf east of the New England States was begun in early June.

[67] Emery, K. O., and Schlee, J. S., 1963, The Atlantic continental shelf and slope—A program for study: U.S. Geol. Survey Circ. 481.

Syntheses of published data and analyses of samples from the Gulf of Maine collected by the U.S. Bureau of Commercial Fisheries and other organizations have provided many interesting results. On the basis of a new cotidal map of the coast, Emery [68] has found that there is an unexpectedly great transfer of tidal energy to the shelf, which may account in part for coarseness of sediments on its surface. Emery also has noted close relations between monthly mean sea levels, water density, and water temperatures and salinities, which he plotted, and amounts of stream runoff for selected rivers, plotted by Donald J. Casey.[68] The relations suggest that the apparent rise of sea level northeast of New York may be explained by increased runoff and that the previously advocated worldwide rise of sea level is compensated northeast of New York by local uplift due to isostatic rebound following retreat of the Pleistocene glaciers. South of New York the apparent rise of sea level appears to be unrelated to runoff and may be due to a worldwide rise of sea level.

On the basis of published data supplied by the Coast and Geodetic Survey, the Woods Hole Oceanographic Institution, and the University of Miami, Elazar Uchupi has compiled a new bathymetric chart of the Atlantic continental shelf, slope, and rise. He distinguishes seven physiographic provinces within the area of the chart: the continental shelf (20 to 70 km wide), the continental slope, the Blake Plateau, the Cape Fear Arch Extension, the Blake Plateau Outer Marginal Escarpment, the Florida Strait and the Pourtales Terrace.[68] Uchupi (Art. 94) also has plotted the distribution of rocks and sediments dredged from the Atlantic shelf and related features. Pre-Quaternary rocks have been dredged from ledges, escarpments, and submarine canyons. Quaternary sediments on the shelf north of New York have large admixtures of glacial detritus; those south of New York are mainly detrital and organic sediments. Variations in textures and compositions are related to currents, latitude, and physiographic setting.

John C. Hathaway, Jobst Hülsemann, John S. Schlee, and James V. A. Trumbull [68] have assembled and adapted equipment for studies of the mineralogy, chemistry, and textures of sediments collected from the shelf and slope. Preliminary work on samples from the Gulf of Maine collected by the Bureau of Commercial Fisheries indicate many differences that can be used to distinguish sediments of varied origins and that will permit more definitive mapping of features on the ocean floor than was previously possible.

[68] *In* Thayer, M. C., ed. 1963, Summary of investigations conducted in 1962: Woods Hole Oceanog. Inst., Dep. Chemistry and Geology, p. 13–23.

### Calcareous sediments of the Bahama Banks

Investigations by P. E. Cloud (2–62) and others show that recent calcareous sediments west of Andros Island resemble those from which some widespread aphanitic and pelletal limestones were formed in the past. These limemuds and pelletal limesands are accumulating beneath subtropical water of salinity averaging greater than 39 parts per thousand and rising locally to 46 parts per thousand over 13,000 square kilometers (5,000 sq mi) of shallow banks in the lee of this 170-kilometer-long island complex. Opposing surface currents that flow around the island and from the Straits of Florida retard exchange between bank and ocean waters, and a high rate of evaporation brings about unusual concentrations of the dissolved solids. Increasing salinity, in combination with elevated temperature and other factors, facilitates a high rate of calcium carbonate withdrawal. Transport from Andros Island may be responsible for about 5 percent of the total sediment. Another 20 percent is of skeletal origin, mainly algal. The remaining 75 percent is believed to be due to chemical precipitation, with subsequent intensive organic pelleting of the clay and silt fractions. Aragonite needles precipitated experimentally from sea water resemble both those found in the raw sediment and those of known algal origin. The range in temperature and salinity of the bank water is believed to be consistent with the formation of the sedimentary needles at equilibrium with it, as shown by analytical oxygen-isotope ratios. Although the biotas are not very diverse, the total biomass and variety are greater than has generally been reported. The more distinctive elements are marine angiosperms, codiacean and dasycladacean algae, sponges, annelids, tunicates, white mud-burrowing fish, and crustaceans. Bacteria in the bank muds were found by F. D. Sisler to reach local concentrations as great as $10^{10}$ individuals per g, wet weight, of sediment, and to have an abundance inversely related to grain size of the sediment. They decompose organic matter, take up oxygen, and evolve carbon dioxide, hydrogen, and perhaps other gases.

## HYDROLOGIC STUDIES

Determination of the relations between water on land and that of the oceans has long been of interest in the Geological Survey. Surface-water discharge of rivers and other runoff has pronounced effects on tides and the composition of water in estuaries, bays, and along the coasts, as illustrated by continuing studies of the Delaware River estuary (p. A125). Sediments and stream-borne wastes are dispersed and deposited in the oceans.

Many Survey coastal cooperative programs have dealt with sea-water encroachment and equilibria between fresh water and salt water in coastal aquifers (p. A126). Amounts of fresh water than can safely be developed on islands and in coastal areas have been the subject of many studies. In some areas, notably in Florida, a major interest is the extent of fresh-water movement to the continental shelf and the process by which this occurs. Publications during the current year describing salt-water—fresh-water relations in coastal areas include:

Long Island, N. Y.: Isbister, John (2–63); Lusczynski, N. J., and Swarzenske, W. V. (1–62); Perlmutter, N. M., and Geraghty, J. J. (2–63); Perlmutter, N. M., and Soren, Julian (1–63);

New Jersey: Gill, H. E. (1–62); Seaber, P. R., Gill, H. E., and Lang, S. M. (2–63); Seaber, P. R. (1–63);

Georgia: Wait, R. L. (2–62);

Florida: Bermes, B. J., Love, G. L., and Tarver, G. R. (1–63); Brown, D. W., Kenner, W. E., Crooks, J. W., and Foster, J. B. (1–63); Barraclough, J. T., and Marsh, O. T. (2–62); Kohout, F. A., and Hoy, N. D. (1–63); Sherwood, C. B., Jr., and Klein, Howard (1–63);

Texas: Anders, R. B., and Naftel, W. L. (1–63);

Oregon: Brown, S. G., and Newcomb, R. C. (1–63); Hampton, E. R. (1–63);

California: Burnham, W. L., Kunkel, Fred, Hofmann, Walter, and Peterson, W. C. (1–63); Evenson, R. E., Wilson, H. D., Jr., and Muir, K. S. (1–62);

Hawaii: Visher, F. N., and Mink, J. F. (1–62).

Studies of the quality and geochemistry of water are contributing both directly and indirectly to marine hydrology. For example, knowledge gained from research on key elements, such as iron, aluminum, and manganese, can now be applied to predict chemical reactions such as flocculation of sediments and precipitation of radionuclides in estuaries where fresh water and salt water meet.

### Delaware River estuary

Studies of the hydrology of the Delaware River estuary underway since 1954 include the relations of river flow and tides, distribution of salinity in the estuary, quality of water of the river, and salt-water encroachment into aquifers from the estuary. E. G. Miller (1–62) concluded that at all times, velocities of tidal currents in the Delaware River, whether upstream or downstream, are related to fresh-water discharge. Measurements of tidal flow during three cycles indicated that the maximum rate of upstream flow exceeded that of downstream flow for a given cycle by from 3 to 11 percent, because downstream flow lasted up to 2 hours longer than upstream flow.

Bernard Cohen and L. T. McCarthy (1–62) reported on salinity of the Delaware estuary on the basis of studies extending from July 1954 to December 1958. They found that the most likely time for salt-water invasion of the estuary was from August to October, when fresh-water outflow was at a minimum and sea level outside the bay was highest; the least likely time is from December to May. The chloride content of the Delaware River is 35 ppm or less, 64 percent of the time at Marcus Hook, Pa., and 95 percent of the time at Philadelphia.

During 1962, winter winds were responsible for extraordinarily low tides and salinity distribution in the Delaware estuary. R. H. Tice, A. C. Lendo, and L. T. McCarthy, Jr., report that on December 31, 1962, strong winds averaging 26 mph for 48 hours, with gusts to 2 or 3 times the average, literally blew the water of the estuary into the Atlantic Ocean. The record low tides of December 31, which left ships stranded and water-supply intakes out of water for as long as 5 hours, were measured at 7 to 9 feet below normal low water (9 to 11 feet below mean sea level) between Trenton, N.J., and Philadelphia, and 5 to 7 feet below normal low water in the lower Delaware River and Delaware Bay. L. T. McCarthy and A. C. Lendo report that during the strong winds, the salt content of the Delaware estuary at the Delaware Memorial Bridge near Wilmington, Del., decreased from 1,730 ppm on December 29 to 182 ppm on December 31.

On January 1, 1963, as the tides returned to normal, the fresh-water flow into the estuary was unable to replace the fresh water outflow of the previous day. As a result, a surge of highly saline water from Delaware Bay caused large increases in salt content along the entire estuary from the bay to just below the Schuylkill River at Philadelphia. The salt content continued to rise until January 9, when it reached a maximum of 6,320 ppm at the Delaware Memorial Bridge. At Chester, Pa., the salt content, which averaged 32 ppm during December, rose rapidly on January 1 and reached a maximum of 1,140 ppm on January 9.

### Biologic study of the Patuxent River estuary, Maryland

Robert L. Cory found in a study of the relations of attachment organisms and marine woodborers to the hydrologic environment within the Patuxent River estuary, Maryland, that barnacles, mud-tube worms, tube-building amphipods, encrusting bryozoans, and algae, in that order, were the principal attachment organisms; marine borers were not active. Wooden test panels, placed at five sites, have been collected monthly and quarterly since November 1962. All attachments occurred before the onset of cold winter weather. Growth was vigorous during October but slight during the winter. Growth rates on the panels varied with depth as well as location. During October 1962, the highest organic production was 9.71 g per m$^2$ on the bottom at the Benedict Bridge and the lowest was 1.55 g per m$^2$ at Solomons Island. From October to January, the highest organic production was 78.43 g per $m^2$ on the bottom at the bridge and the lowest was 18.83 g per $m^2$ at Solomons Island.

### Salinity distribution in estuaries

C. Lai developed a theoretical equation to predict the change in salinity distribution in estuaries by generally following the concepts advanced by Ippen and Harleman.[69] The salinity gradient predicted by the equation was compared with the observed gradient in the San Lorenzo River estuary in California. The comparisons indicate that the equation does not account for complicated boundary geometry, especially during periods of high tide.

### Unsteady flow in tidal reaches

A theoretical analysis of unsteady flows of homogeneous density in tidal reaches by C. Lai led to a set of nonlinear partial differential equations. These equations were transformed into characteristic equations, and then organized into difference equations suitable for high-speed digital computers. As compared with the method of power series investigated by Baltzer and Shen,[70] this model is more suitable for those tidal reaches with complex geometries, as for example, reaches with variable cross sections or with tributaries.

### Discharge of tidal streams to Puget Sound

J. E. Cummans has found that discharge of tidal streams entering Puget Sound can be computed from a base rating curve for a gage located in the estuary and an adjustment curve for degree of submergence, obtained from one tidal gage in the sound. When height of tide above channel bottom is less than 30 percent of water depth at the stream gage the base rating can be used directly. When height of tide becomes 60 percent of depth the base rating is within 5 percent of true discharge. Comparison of mean daily discharges computed for 2 months by Cummans' method with mean daily discharge computed by the more elaborate rating-fall method showed that two-thirds of the days differed by less than 5 percent and that the maximum difference was less than 10 percent.

### Tidal flooding at Atlantic City, N.J.

D. M. Thomas and G. W. Edelen, Jr., (1–62) report that on September 12, 1960, and again on March 6 and 7, 1962, storms and high tides caused extensive flooding at Atlantic City, N.J., and on other parts of Absecon Island. During the 1960 flood, caused by Hurricane Donna, the maximum floodmark elevations were about 6 feet and flooding was confined mainly to low areas on the inland shore of Absecon Island. During the 1962 flood, caused by a slow-moving extratropical storm superimposed on excessively high tides, the maximum floodmark elevations were almost 12 feet at the southwest end of Absecon Island, and elevations of 8 feet were recorded in downtown Atlantic City.

### Storm flooding on the north coast of Puerto Rico

Swells generated by distant Atlantic storms produced 25-foot waves along the north coast of Puerto Rico November 17, 1962, and slightly lower waves January 1, 1963. Waves in November exceeded known heights in recent years, caused structural damage, flooded highways, and cut high beach ridges. Tide gages in sheltered ports were not strongly affected.

## SALT-WATER INTRUSION IN COASTAL AQUIFERS

### Long Island

N. J. Lusczynski and W. V. Swarzenski report that calcium, magnesium and bicarbonate are enriched in comparison with the source waters in fresh-water–salt-water blends in the Magothy(?) Formation near the deep salty-water wedge in southwestern Nassau County, Long Island, N.Y. Modifications from theoretical mixtures are caused by chemical and physical reactions between the different kinds of water and by exchange reactions between the minerals in the unconsolidated deposits and the minerals in the water.

Speculation on the position of the salty-water front on the south shore of Long Island, N.Y., in the Lloyd Sand Member of the Raritan Formation, the deepest artesian aquifer, has ranged in the past from several miles offshore to many miles away, at the edge of the continental shelf. Lusczynski and Swarzenski conclude from drilling, electric-log, and chloride data that the leading edge of the salty water in the upper or lower part of the Lloyd Sand Member is at or near Coney Island in Kings County, at or near Rockaway Park in Queens County, at or near Atlantic Beach and Long Beach, and not more than 3 miles offshore from Jones Beach, in Nassau County. Moreover, N. M. Pearlmutter found salty water in the Lloyd Sand Member in test wells drilled at Fire Island State Park and at Bellport Coast Guard Station in Suffolk County. The leading edge of the salty water in the Lloyd Sand Member evidently is at or near the barrier beaches along the entire south shore of Long Island. The position of the salty water in the Lloyd Sand Member is a natural situation except at Long Beach, where heavy pumpage has caused salt-water contamination of at least one of the supply wells. Studies of the width of the zone of diffu-

[69] Ippen, Arthur T., and Harleman, Donald, R. R., 1961, One dimensional analysis of salinity intrusion in estuaries: Corps of Engineers, U.S. Army, Tech. Bull., 5.

[70] Baltzer, R. A., and Shen, John, 1961, Computation of homogeneous flows in tidal reaches by finite-difference method: Art. 162 *in* U.S. Geol. Survey Prof. Paper 424-C, p. C39–C41.

sion in the Magothy(?) Formation between Atlantic Beach and Lido Beach suggest that the zone of mixed salt and fresh water may be 3 to 5 miles wide in the Lloyd.

John Isbister (2–63) described a unique occurrence of fresh water at Center Island, near Oyster Bay, Long Island. Although surrounded on all sides by sea water, Center Island has ample supplies of fresh water thanks to a fortunate combination of geology and hydrology. Shallow wells tap fresh water that floats on a salt-water lens in an unconfined aquifer. Deep wells tap fresh water in a confined aquifer that is sealed off from the overlying salty marine water by thick clay strata, and is replenished by infiltration on the main body of Long Island.

#### Puget Sound

Several wells at Hyada Park, on an upland coastal area near Tacoma, Wash., produce water that with continued pumping becomes too saline for use, according to G. E. Kimmel (Art. 50). Although precipitation is abundant, recharge to the body of fresh ground water beneath the area apparently is limited by the low permeability of the glacial till that mantles the upland.

#### Effects of fluctuations in sea level on relations between fresh and salt ground water

Studies by J. E. Upson of the occurrence of salt ground water in the Netherlands have led to the suggestion that relationships between fresh and salt ground water along coasts may be rendered complex by postglacial fluctuations of sea level, and attendant shore processes.

Contrary to the usual situation, the coastal region of the Netherlands extending 20 to 30 kms inland is underlain by moderately salty water which forms in reality a gigantic zone of transition. This is thought to result from dispersion and diffusion processes accompanying the so-called Atlantic marine transgression 7,500 to 5,000 years ago.

Superimposed on this zone in the Zuider Zee region is a thin sheet of much saltier water introduced by swift sea transgressions over coastal marshlands generally in the most recent 2,500 years. These supposedly result from local break-throughs of a coastal barrier, but crustal subsidence may play a minor role. In the coastal dune strip are linear lenses of fresh water that supply many coastal cities and towns. These lenses were developed and maintained by infiltration of rainfall in the past few thousand years when the dunes became sufficiently high and extensive to absorb appreciable quantities of water. The fresh-water lenses beneath the coastal dune strip formed above the seaward, saltier parts of the older zone of transition, and are separated from it by a sharp interface, 10 to 30 in. thick, that approaches the classic concept of the fresh water-salt water interface.

## ASTROGEOLOGIC STUDIES

The major long-range objectives of the studies being conducted by the Branch of Astrogeology are to determine and map the stratigraphy and structure of the Moon's crust, to work out from these the sequence of events that led to the present condition of the Moon's surface, and to determine the processes by which these events took place. The studies have been made in cooperation with the National Aeronautics and Space Administration.

### *LUNAR AND PLANETARY INVESTIGATIONS*

Geologic mapping of the Moon involves discrimination of the different materials exposed on the lunar surface and their assignment to geologic units, the determination of the photometric characteristics of these materials, delineation of the boundaries of the units, and determination of their stratigraphic sequence.

Geologic maps of the Kepler and Letronne regions of the Moon have been published (R. J. Hackman, 1–62; C. H. Marshall, 1–62), preliminary maps of the Copernicus and Appennine regions are completed, and a map of the Riphaeus Mountains region is nearly completed. Mapping is in progress in twelve other regions. Completed or nearly completed mapping covers about 1,750,000 square kilometers, and mapping in progress 3,500,000 square kilometers.

Geologic studies have been concentrated in and near the Lansberg region of the Moon, the nominal target area for unmanned lunar probes of the Ranger and Surveyor projects. The Lansberg region comprises 4 quadrangular map areas: Copernicus, Kepler, Letronne, and Riphaeus Mountains. When mapping of the Riphaeus Mountains region has been completed, the geology in the 4 regions will be compiled at a scale of 1:2,000,000 on the U.S. Air Force Aeronautical Chart and Information Center topographic map of the Lansberg region.

The thickness of the Apenninian Series of the Imbrian System in the Lansberg region has been studied by R. E. Eggleton (1–63). The Apenninian forms a great sheet of material surrounding Mare Imbrium, and is exposed in about 20 percent of the area of the Lansberg region. The Apenninian was deposited on a surface abundantly pockmarked with craters of various sizes. The obscuring of individual craters by the Apenninian blanket increases as crater size decreases. An estimate of the thickness of the Apenninian has been made on the basic assumption that the thickness equals the ideal unmodified depth of the smallest craters that are barely perceptible through the blanket. In each 4° rectangle of the Lansberg region the smallest discernible pre-Apenninian crater was found, and the original crater depth was calculated from the empirical relation between depth and diameter in unmodified or slightly modified lunar craters. These depths, taken as the local thickness of the Apenninian blanket, were plotted on a fence diagram. These data show that the Apenninian has an average thickness of about 600 m in the eastern three-fourths of the Lansberg region. In the eastern half of the region there is a general decrease in thickness toward the south, radially away from the inner Mare Imbrium basin. These results support the hypothesis that the Apenninian Series is ejecta from Mare Imbrium, analogous to rim materials of craters like Copernicus.

The thickness variations of the Procellarian System in the Lansberg region have been studied by C. H. Marshall (2–63). The Procellarian, exposed over 70 percent of the Lansberg region, comprises mare material and is characterized by a surface of low relief with scattered scarps, ridges, and domes. The buried pre-Procellarian surface was reconstructed in part by estimating the original depth of partly buried craters, and in part by extrapolating the geology adjacent to the margins of the Procellarian. From this reconstruction a preliminary isopachous map showing the thickness of the Procellarian was drawn. The Procellarian mare material (in which some pre-Imbrian marelike material and some Apenninian material may be included) has an average thickness in the Lansberg region of about 1,100 m and a volume of about 1 million cu km. Mare ridges occur in areas underlain by thick Procellarian deposits, and domes commonly occur in areas of thin Procellarian deposits. The trends of mare ridges and scarps may be the result of renewed movements along pre-mare faults.

The albedos of lunar geologic units are being examined statistically by C. W. Davis, A. T. Miesch, R. N. Eicher, and E. C. Morris (1–63), in order to derive parameters that may characterize the units. Digitized microphotometer readings are taken at 1-mm intervals along traverses 1 mm apart across full-moon photographs at a scale of 1:2,000,000. The readings obtained are integrated values for the light transmitted by the photograph over an area 0.1 mm square. The data, which are recorded on paper tape and assigned to specific geologic units, are to be converted to a form suitable for input into a Burroughs 220 computer. The computer is programmed to compute the bulk statistics of the brightness of given geologic units. Textural statistics will be determined by comparing the characteristics of "cells" containing different numbers of original data points, and these statistics are to be computed both on the original data and on deviations from computed regional trend surfaces. The readings will be reduced to standard photometric values by including points in the traverses at which normal albedos have been determined.

In another photometric study, by R. G. Henderson and W. A. Fischer (1–63), a single microdensitometer traverse across a lunar photograph was analyzed using second derivatives, Fourier integrals, and autocorrelation techniques. The Fourier analysis allows geologic units to be distinguished on the basis of relative maximum amplitudes and frequency range of the brightness

Brightness variations of stratigraphic units in the Lansberg region have been studied by R. J. Hackman (1–63), who has compiled an isotonal map from measurements made with a microdensitometer on a full-moon photographic plate. Emphasis in this reconnaissance study was on distinguishing variations within the darker tone values characteristic of the maria. The measured values appear to be related to composition and texture of material rather than to topography.

A search of the literature of E. C. Morris (1–63) revealed 29 measurements of normal albedo in the Lansberg region on which data were available as to both size of area measured and location. These measurements, all of which had been determined photographically, were plotted on a base map of the Lansberg region on which the light and dark facies of the mare material were shown. The dark facies has albedos less than 0.060; the light facies has albedos from 0.065 to 0.072; values on post-mare craters range up to about twice these, with the highest value 0.135 in the center of the crater Copernicus. This preliminary study is to be followed by photoelectric measurements of albedos which will be used to calibrate photographic plates for photometric studies.

The albedo measurements obtained from the literature were compared with the values on the isotonal map. For areas of the Procellarian mare material a relationship exists that may be represented by

$$\log(\text{tone}) = 6.0(\text{albedo}) + 0.5$$

For areas of greater brightness the plot of albedos against tone values has a large scatter, indicating the insensitivity of the tone scale in these areas.

In 1961, K. Kordylewski of Krakow University reported luminous clouds in the $L_4$ and $L_5$ libration regions of the Earth-Moon system. These are regions of gravitational equilibrium that lie in the Earth-Moon plane at the vertices of equilateral triangles which share a common base extending from the center of the Earth to the center of the Moon. If the "Kordylewski clouds" actually exist, they are probably composed largely of particles ejected from the Moon by hypervelocity impact of asteroidal and cometary material. Accurate measurements of such clouds may permit an estimate of the rate of flux of material ejected from the Moon.

A systematic photographic investigation of the libration regions was begun by Morris and H. G. Stephens (1–62) during the summer of 1962 at Mt. Chacaltaya, Bolivia. Glass photographic plates exposed in July and August and covering a sky area 45° by 37° in the $L_5$ region were examined with a microphotometer, but no clouds of particulate matter were detected. Because the residence time of particles in the libration regions may be brief and the supply of matter sporadic rather than constant, the investigations are to continue.

## CRATER INVESTIGATIONS

These investigations include field studies of terrestrial craters, hypervelocity impact experiments with rocks and other materials, studies of behavior of rocks under high shock loads, and experimental and field studies of shock metamorphism in rocks.

A high-density polymorph of $SiO_2$ was found in the coesite-bearing Coconino Sandstone of Meteor Crater, Ariz., by E. C. T. Chao, J. J. Fahey, Janet Littler, and D. J. Milton (6–63). The new mineral was named "stishovite" in honor of the Russian experimentalist who shortly before had synthesized the phase at temperatures of 1200°–1400°C and a pressure of about 130 kilobars.

Because it occurs sparsely in very fine grains, stishovite has not been observed in thin section. However, nearly pure samples have been obtained by differential solution of the sandstone in hydrofluoric acid. X-ray power data on the stishovite concentrate agree with data on the synthetic material in both d-spacing and intensity of reflections. The reflections have been indexed and are consistent with the space group P4/mnm or rutile. Stishovite is the first mineral recognized in which silicon occurs in octahedral rather than tetrahedral coordination with oxygen. The presence of stishovite at Meteor Crater is attributed to the transient shock pressure accompanying meteorite impact. The minimum peak pressure indicated by the presence of stishovite is more than five times that previously estimated from the presence of coesite.

Another mineralogical transformation possibly induced by shock is the formation of maskelynite. Maskelynite, a major constituent of the rare meteorites of the shergottite class, is an isotrophic glass with the composition of plagioclase and pseudomorphous after that mineral. Except for the substitution of maskelynite for ordinary plagioclase, shergottite is similar to many terrestrial gabbros. To produce a shergottitelike material experimentally, two wafers of gabbro from the Stillwater Complex, Mont., were subjected to explosively induced shock by D. J. Milton and Paul De Carli (1–63, 2–63) of the Stanford Research Institute. The peak shock pressure in one wafer was 600–800 kilobars, with a shock temperature of 1700°–2100°C; the peak shock pressure in the other wafer was 250–350 kilobars with a maximum temperature of 200°–300°C. In both wafers the pyroxene remained crystalline. In the more strongly shocked specimen the plagioclase was transformed into a vesicular glass. In the less intensely shocked specimen, the plagioclase was entirely converted to maskelynite, which, although completely isotropic, still shows the cleavage cracks and crystal outlines of plagioclase. The less intensely shocked material resembles shergottite, suggesting that meteoritic maskelynite was formed by shock at a comparatively low temperature rather than by thermal melting. Shergottite may be lunar material shocked and ejected by an impact event on the Moon.

Relations bewteen dimensions of impact craters and the properties of the target and projectile have been established on the basis of a large number of high-velocity and hypervelocity impact experiments on rock targets by H. J. Moore, 2d (1–63), and D. E. Gault of the National Aeronautics and Space Administration. The ratio of crater depth to projectile diameter (p/d) plotted against the ratio of projectile density to target density times the ratio of the projectile velocity to acoustic velocity of the target

$$\frac{\rho_p}{\rho_t}\cdot\frac{V}{C}$$

gives a nonlinear curve. The curvature may result either from a series of impact regimes or from a continually varying relation due to the changing strength of the target. To take account of the changing strength of the target with pressure, the value $(S_t/\rho_t)^{1/2}$, where $S_t$=target strength, may be substituted for C. Such a substitution should lead to a more linear relationship between the crater dimensions and the properties of the target and projectile.

Moore (2–63), Gault, and R. W. MacCormack, of the National Aeronautics and Space Administration, have utilized this relation to compare craters produced in rocks and metals with those produced in water. The approximate deformation strength for a hemispherical water crater is equal to the sum of the strengths due to hydrostatic pressure head, to surface tension, and to viscosity. Deformation strengths computed in this manner are in substantial agreement with deformation strengths calculated by a formula derived on a theoretical basis by Charters and Summers for impact craters formed in metal targets in the fluid-impact regime.

Using this calculated deformation strength for water, fluid-impact craters produced by water drops on water can be correlated with fluid-impact craters in rock and metal targets. For rocks and metals, the product of target density and heat of fusion provides a maximum value for $S_t$, and the unconfined compressive strength provides a minimum value. However, correlation with water craters is better when the shear strength and density of 49 kilobars are used for $S_t$ and $\rho_t$ respectively.

An inexpensive technique for determining the shock equations of state of rocks has been developed by M. H. Carr (1–63). The rock specimen, in the form of a rod, is placed in contact with an aluminum rod. A shock wave passes through the aluminum and then through the specimen. The speeds of the shock wave in aluminum and in the specimen are determined by measuring the times of arrival of the shock wave at strain gages bonded to the two materials. From these two speeds the shock equation of state is determined using an impedance match solution.

A preliminary study of the thermoluminescence of samples from several stratigraphic horizons exposed in the meteorite craters at Odessa, Tex., has been made by C. H. Roach, G. R. Johnson, J. G. McGrath, V. M. Merritt, and T. S. Sterrett (1–63). The stress associated with meteorite impact greatly reduced the total thermoluminescence of limestone, calcareous sandstone, and caliche. However, the ratio of the intensities of the low to the high temperature peaks of the glow curves is higher in stressed than in unstressed limestone and calcareous sandstone. The glow curves of the stressed caliche show peaks; those of unstressed caliche are smooth.

In solid-state studies at Project GNOME near Carlsbad, N. Mex., the same investigators have found that shock-induced thermoluminescence in the rocks enclosing an underground nuclear explosion extends farther than the explosion-produced radioactivity. Other solid-state methods, such as exoelectron emission and single-crystal X-ray techniques, may also be able to detect shock-induced properties of rocks beyond the limits of radioactivity produced in underground nuclear explosions. Solid-state techniques may thus prove useful in the detection of clandestine explosions.

An instrumentation project was started in July 1962 to develop certain types of electronic equipment and techniques of measurement. An apparatus has been developed for measuring the luminescence emitted from minerals as they are heated at a rapid linear rate from room temperature to 400°C. This thermoluminescence apparatus will be used in the solid-state investigations for studies of shock-induced thermoluminescence of rocks exposed in terrestrial meteorite craters. A mobile analytical laboratory is being equipped to make solid-state investigations in the field. Several other problems of instrumentation are under study.

Vesicular glass from a highly disturbed structure in gneiss at Köfels in the Austrian Tyrol, examined by D. J. Milton (3–63), shows features inconsistent with the volcanic origin usually ascribed to it. Quartz inclusions have been melted, but the silica glass remains in discrete drops that have not dissolved in the matrix glass. Such silica glass inclusions have been observed in glasses formed by friction along a thrust fault and by meteorite impact, but not in volcanic glasses. The explosion of a small nuclear device buried behind a steep slope produced a geologic structure that is a good small-scale model of that at Köfels. Impact of a large meteorite would have an effect analogous to that of a subsurface explosion, as has been suggested by F. E. Suess, and is a likely cause of the Köfels feature.

Mapping of the Flynn Creek structure in north-central Tennessee by D. J. Roddy tentatively confirms its suggested impact origin. A central core of brecciated limestones is surrounded by a circular rim of folded and faulted Upper Ordovician limestones. Steeply dipping, slightly brecciated limestones, locally containing shatter cones, crop out in the central part of the breccia core. The Chattanooga Shale of Late Devonian and Mississippian age unconformably overlies the disturbed structure, providing a minimum age (Art. 74).

## COSMOCHEMISTRY AND PETROGRAPHY

Studies are being made of the chemical, petrographic, and physical properties of materials of extraterrestrial origin, materials associated with terrestrial impact structures, and particles of possible cosmic origin.

The physical and chemical properties of tektites, glassy materials thought to have originated from impacts on the Moon's surface, are being actively studied. The present state of knowledge has been reviewed by E. C. T. Chao (5–63). Tektites from all strewn fields have the following physical characteristics in common: They are completely amorphous glass without microlites. Their approximate range of bulk specific gravity is 2.30 to 2.51, and of bulk index of refraction, 1.480 to 1.519. All tektites show flow structure, and nearly all contain inclusions of lechatelierite or other glasses. The index of refraction of these inclusions ranges from 1.46 (pure silica glass) to 1.495. These inclusions, which commonly show an extremely intricate wavy or criss-cross pattern, indicate that at the time of tektite formation, materials of different original composition coexisted in a highly fluid state, presumably at temperatures of 2000°C or higher, and that subsequent cooling was rapid.

The content of silica in tektites ranges from about 68.0 to 82.7 percent. Compared to igneous rocks of corresponding silica content, they are low in alkali content, and all except the bediasites of Texas have a high lime and magnesia content. The water content is extremely low, less than 0.02 percent, and the ferric/ferrous ratio is very low, about 0.05. The minor-element content is similar to that of terrestrial rocks.

All the physical and chemical characteristics of tektites are compatible with an hypothesis that they formed by the melting of siliceous igneous rock with volatilization of some of the alkalis by impact of a meteorite, asteroid, or comet. Spherules of nickel-iron in some philippinites may be remnants of the impacting object. The low ferric iron content of tektites suggests that their formation did not take place in the Earth's oxygen-rich atmosphere; furthermore, no crater is known to be associated with any of the strewn fields. A lunar impact origin seems indicated.

Tektite localities in the Philippines, Viet Nam, Thailand, Java, and Australia were visited by Chao (1–63, 4–63). The philippinites occur in or above sedimentary deposits of middle Pleistocene age. The javanites occur on top of a gravel of middle Pleistocene age. The tektites of the Asian mainland occur in laterized soil of probable late Pleistocene age. Some of the australites occur above a middle Pleistocene aeolianite. It is not yet possible to state without reservation that all these tektites fell contemporaneously, but the evidence is consistent with the hypothesis of a single shower that probably fell in late Pleistocene time.

A. N. Thorpe, F. E. Senftle, and F. Cuttitta (1–63, 2–63, 3–63) found the magnetic susceptibility of tektite glass to be closely related to the content of ferrous or of total iron. Measurement of the susceptibility thus affords a rapid nondestructive method of determining the iron content of tektites. The specific magnetic susceptibility of ferrous iron in tektites calculated from these data shows that the orbital magnetic moment is almost completely quenched.

Pete Signer found extraction of radiogenic argon from samples of bediasite to be unexpectedly difficult. Several hours were required to extract the argon from melts at temperatures as high as 1800°C. Nevertheless, the K/Ar ages indicate that at the time of formation of tektites an extremely efficient outgassing took place. The temperatures and time available seem entirely inadequate for such outgassing by ordinary diffusion. Outgassing must have occurred by some other method, perhaps as a phenomenon of extreme shock.

Although tektites are believed to have been produced by impact, they are quite different from the highly heterogeneous, vesicular, crystal-bearing impactite glasses found at meteorite craters. This gap is partially bridged by a dense glass found in small amounts in the Otting quarry at the Ries crater in southern Germany, and studied by Chao and Janet Littler (2–62, 2–63). The glass contains lechatelieritelike inclusions and has a flow structure very similar to that of tektites; its magnetic susceptibility is similar to that of some indochinites and philippinites. It differs, however, from tektites in containing crystal fragments. The composition of the glass suggests that it was derived from biotite granitic gneiss of the basement underlying the Ries crater. Although they have the same K/Ar age, the dense glass and the moldavites of Czechoslovakia differ in chemical composition, so that they can have no direct connection.

C. W. Mead, Chao, and Littler (1–63, 2–63) have studied metallic spheroids, in the soil around Meteor Crater, Ariz., which condensed from meteroritic material melted or vaporized at the time of the impact. The particles commonly are about 0.5 mm in diameter and are characteristically coated by siliceous glass that contains minute fragments of quartz. The spheroids consist mainly of kamacite, with geothite, maghemite, and an unidentified phase that may be schreibersite. The kamacite is finely granular and has a highly variable composition. Some has only 2 percent nickel, much less than the parent meteorite. The spheroids are very similar to those that occur in some philippinities, which suggests that the latter also originated by meteorite impact.

## STUDIES FOR SPACEFLIGHT PROGRAMS

Studies for the spaceflight program are being undertaken to aid in the design of space-flight experiments and the planning of space missions. An investigation of the lunar surface, in connection with planned Surveyor and Ranger missiles, is being directed by E.M. Shoemaker. The studies are to include testing of the physical-properties experiment on the Surveyor lightweight payload, field testing of the TV cameras on natural terrains around Flagstaff, Ariz., and exercises in interpreting the results recorded by the TV system. Plans also included analyses of the results from the Ranger impacting capsules in fiscal 1964.

Investigations of the frequency distribution of craters on the Moon show that secondary-impact craters dominate the population of craters of about 1 kilometer or less in diameter, and that these secondary-impact craters have approximately the same frequency-distribution slope as the larger craters. The frequency of impact of micrometeoroids on the lunar surface and secondary particles produced by the micrometeoroids will produce small craters, having diameters of the order of 1 to 2 millimeters, which can be observed with the Surveyor TV system. These events will probably be observed directly on a surface area of about 1 square meter that can be monitored every hour or so by the system.

The existence of an "atmosphere" of dust about the Moon has been suggested by D. E. Gault, Shoemaker, and H. J. Moore II (1–62, 1–63). In the absence of any appreciable gaseous atmosphere, the surface of the Moon is subjected to continuous bombardment by projectiles covering the complete size-spectrum of interplanetary debris. Each projectile, striking the lunar surface with full cosmic velocity, excavates and sprays secondary fragments into ballistic trajectories across the lunar surface.

Experimental studies of hypervelocity impact into rock at the Ames Research Center indicate that between $10^2$ and $10^3$ fragments with masses greater than the projectile mass will be produced for each impact at velocities from 15 to 30 kilometers per second. An analysis of the integrated effect of the continuous bombardment by interplanetary debris on the Moon suggests that the flux of ejected fragments of a given mass will be at least $10^3$ and probably $10^4$ times the flux of interplanetary projectiles of the same given mass. Although some of these fragments should be ejected with sufficient velocity to escape the lunar gravitational field, most of the excavated mass will be ejected with velocities less than 500 meters per second and will return to the lunar surface to cause secondary-impact events within a few kilometers of the primary crater. A tremendous number of small fragments (whose integrated mass is but a small fraction of the total ejected mass) should travel most of the way around the lunar circumference before returning to the surface. The great bulk of the excavated fragments will never rise to more than a few kilometers above the lunar surface. With a sufficiently high flux rate of interplanetary debris, the continuous production of secondary fragments could establish a "steady state" cloud of particles flying above the lunar surface. The spatial density of the fragments at the lunar surface is estimated to be of the order of $10^5$ to $10^7$ times the spatial density of the interplanetary debris.

An exact assessment of the population of the secondary fragments cannot yet be made, owing to uncertainty in the flux of interplanetary debris which impacts the lunar surface. If, however, one accepts a mass-number distribution for the interplanetary debris midway between those suggested by Watson and by Whipple, then a secondary flux rate onto the lunar surface of the order of one particle/m$^2$/sec is obtained for fragments having masses equal to or greater than $10^{-10}$ grams. This flux rate corresponds to a spatial density at the lunar surface of approximately $10^{-2}$ particles/m$^3$.

C. R. Warren has suggested that the surface material of the Moon has the texture of a skeletal fuzz, several millimeters or centimeters deep. The solid part of the fuzz is thought to consist of randomly oriented linear units, with or without enlarged nodes, which may either mesh or branch. This model is in accord with the photometric properties of the lunar surface. The skeletal fuzz may be formed by the etching of the cell walls of vesicular rock by solar protons (Art. 39).

### *LUNAR BIBLIOGRAPHY*

Card indexes to lunar and planetary literature of general scientific interest are being compiled. These serve not only as reference tools but also as guides to acquisition of specialized library materials in astrogeology. At present the lunar index contains about 7,700 references to the surfaces and environment of the Moon. A similar index to the literature of meteorite craters has been begun; it contains about 450 references.

## GEOPHYSICAL INVESTIGATIONS

### *STUDIES OF THE CRUST AND UPPER MANTLE*

The U.S. Geological Survey is continuing its active investigation of the properties and broad-scale features of the crust and upper part of the mantle of the earth. These studies have received added emphasis with the publication this year of the proposed United States Program for the International Upper Mantle Project by the National Academy of Sciences–National Research Council. At the present time, the Geological Survey is making major contributions to knowledge of the crust and upper mantle in the fields of explosion, seismology, earthquake seismology, gravity and isostasy, heat flow, earth currents, and areal magnetism. Much of the work in seismology and magneto-telluric currents has been sponsored by the Advanced Research Projects Agency of the Department of Defense as a part of project VELA UNIFORM. Other contributions to our knowledge of the outer shells of the earth are of course being made from other investigations—particularly in field mapping and regional geophysical investigations, geochronology, properties of geological material, volcanology, and experimental geochemistry—but insofar as these contributions are directed primarily toward other goals, they are reported elsewhere in this volume.

#### Seismic-refraction studies

The network of recordings of seismic waves generated by underground nuclear and chemical explosions has been expanded to include an area extending from the California coast to eastern Colorado and from northern Idaho to the border of the United States and Mexico. In addition, seismic waves have been recorded along a profile extending north from the Gulf Coast to the center of Mississippi. About 2,000 recordings have been made in all, of which about 1,700 are from chemical explosions and 300 from underground nuclear explosions. From these recordings it has been possible to deduce variations in the thickness of the crust and in the seismic velocities of the upper-mantle rocks in this broad region. Additional information has been obtained in some places on the nature of seismic layering within the crust.

Crustal thickness along the California coast as determined from two reversed seismic-refraction profiles extending from San Francisco to Los Angeles is generally about 25 kilometers.[71] Interpretation of a profile extending from San Francisco to Fallon, Nev., indicates that the crust thins eastward to less than 20 km under the Central Valley of California, and then thickens abruptly to more than 40 km under the Sierra Nevada.[72] Farther east, in the Basin and Range province of eastern California, Nevada, southwestern Utah, and northwestern Arizona, a detailed network of seismic profiles has been interpreted by several investigators (Eaton; [72] Pakiser and Hill; [73] Roller and Healy; [74] and Ryall and Stuart).[75] Crustal thickness in the Basin and Range province was found to be generally in the range 25 to 35 km, and to be directly related to regional altitude above sea level.[76]

North of the Basin Ranges, in the Snake River Plain of Idaho, crustal thickness is interpreted to be about 45 km,[76] and to the east, in the Colorado Plateaus, crustal thickness is interpreted to be about 40 km.[75] Crustal thickness interpreted from 2 profiles in the Great Plains province in eastern Colorado and eastern New Mexico is about 50 km (Stewart and Pakiser, 1–62; Jackson, Stewart, and Pakiser).[77] Crustal thickness has not been determined directly in the southern Rocky Mountains of Colorado, but it has been inferred to be about 60 km from a profile extending about 300 km west into the mountains from a shot point in southeastern Colorado. Recordings along this profile failed to reveal evidence of the upper mantle from first arrivals of shock waves,[76] and this implies a thicker crust than that in eastern Colorado.

Regionally significant variations in the speed of compressional waves in the upper-mantle rocks have been revealed by the program of long-range seismic-refraction profiling, and these are related to crustal thickness and regional altitude above sea level. The speed of compressional waves in the upper-mantle rocks in the broad region south of the Snake River Plain and west of the Colorado Plateaus is generally in the range 7.7 to 7.9 km per sec, except along the California coast where it is about 8.0 km per sec. In the Colorado Plateaus, upper-mantle speeds of about 8.0 km per sec are indicated. In the Great Plains region, the average speed of compressional waves in the upper-mantle rocks is about 8.2 km per sec. Thus, upper-mantle speeds vary by about 6 percent in the Western States. A similar variation in upper-mantle densities can be inferred from the seismic data.[76]

With few exceptions, the speed of compressional waves in the upper layer of the crust, below the veneer of sedimentary rocks, is about 6.0 km per sec. In the Great Plains of eastern Colorado and eastern New Mexico, evidence was found for material with a seismic speed of about 6.7 km per sec at depths of 20 to 30 km (Stewart and Pakiser, 1–62; Jackson, Stewart, and Pakiser); [77] this speed is appropriate for material of gabbroic composition. Material of similar seismic speed was found in the Snake River Plain at depths less than 10 km.[76] This places a lower limit on the depth to which anomalously dense bodies defined by gravity can extend.[78] Reflections and secondary refractions of seismic waves indicate that this layer is also probably present at a depth of about 20 km in the Basin and Range province.[72, 74]

In summary, isostatic compensation on a scale that includes many geologic provinces is affected by variations in the density of the rocks of the upper mantle. Where the density (inferred from velocity) is high, such as in the Great Plains province, the crust is relatively thick; where the density (inferred from velocity) is relatively low, such as in the Basin and Range province, the crust is much thinner. Within the Basin and Range province, and perhaps others, a direct relation exists between regional altitude above sea level and

[71] Healy, J. H., 1963, Crustal structure along the coast of California from seismic-refraction measurements: Jour. Geophys. Research, v. 68. [In press]

[72] Eaton, Jerry P., 1963, Crustal structure between Eureka, Nevada, and San Francisco, California, from seismic-refraction measurements: Jour. Geophys. Research, v. 68. [In press]

[73] Pakiser, L. C., and Hill, D. P., 1963, Crustal structure in Nevada and southern Idaho from nuclear explosions: Jour. Geophys. Research, v. 68. [In press]

[74] Roller, J. C., and Healy, J. H.. 1963, Crustal structure between Lake Mead, Nevada, and Santa Monica Bay, California, from seismic-refraction measurements: Jour. Geophys. Research, v. 68. [In press]

[75] Ryall, Alan, and Stuart, David J., 1963, Traveltimes and amplitudes from nuclear explosions—Nevada Test Site to Ordway, Colorado: Jour. Geophys. Research, v. 68. [In press]

[76] Pakiser, L. C., 1963, Structure of the crust and upper mantle in the western United States: Jour. Geophys. Research, v. 68. [In press]

[77] Jackson, W. H., Stewart, S. W., and Pakiser, L. C., 1963, Crustal structure in eastern Colorado from seismic-refraction measurements: Jour. Geophys. Research, v. 68. [In press]

[78] Hill, D. P., 1963, Gravity and crustal structure in the western Snake River Plain, Idaho: Jour. Geophys. Research, v. 68. [In press]

crustal thickness; in the basin ranges the properties of the upper-mantle rocks are nearly uniform. Differences in the properties of the crust and upper mantle seem to be related to Cenozoic geology. The Basin and Range province has been dynamically active in Cenozoic time (block faulting and widespread volcanism); the Great Plains province has been relatively stable.

Seismic waves from marine explosions detonated by the Scripps Institution of Oceanography during ocean-borne seismic profiling along the northeast coast of Hawaii in April 1962 were recorded by seismographs of the Hawaiian Volcano Observatory network. These data interpreted by Jerry P. Eaton provided segments of refraction travel-time curves for ranges of 35 to 56 km (Hilo) and 63 to 88 km (Pahoa, Mauna Loa, Uwekahuna, North Pit, Ahua, and Desert). They indicate apparent wave velocities of about 7.0 km per sec and 8.1 km per sec for the oceanic crust and for the upper mantle, respectively, beneath eastern Hawaii. The Mohorovicic discontinuity appears to lie at a depth of only 12 km beneath Hilo; and beneath Pahoa and the summit region of Kilauea it appears to lie at a depth of about 14 km.

Much new information has been obtained on the properties of the different seismic phases, such as $P_g$, P, $P_n$, and reflections from crustal layers and the Mohorovicic discontinuity.[71 72 74 75]

### Earthquake seismology

Jerry P. Eaton has been studying the earthquakes in the vicinity of Derby, Colo., in cooperation with geophysicists at the Colorado School of Mines and Regis College. The first earthquake of the sequence was recorded on April 24, 1962, and other earthquakes have continued to the present. More than 300 earthquakes have been recorded on seismographs maintained by the Colorado School of Mines, Regis College, and the Geological Survey. The largest Richter magnitude of the sequence on December 5, 1962, was about 4. The earthquakes have been widely felt in the Denver area. Analysis of recordings indicates that the epicenters of the earthquakes are northeast of Denver at Derby, and their focal depths are about 15 km.

### Gravity studies

Willie T. Kinoshita has recently completed a Bouguer gravity map of the island of Hawaii (Art. 89). The map shows local gravity highs of 105 to 130 milligals over 4 of the 5 volcanoes that make up the island. Hualalai is at the north end of a 55-milligal high which is centered about 8 miles south of the summit. The larger anomalies generally have higher gradients on their west than on their east sides. Preliminary analysis of the gravity data suggests that large masses of dense rock, probably a combination of intrusive bodies and dense flows, extend to near the surface under all of the volcanoes except Hualalai.

### Isostatic recovery and viscosity of the upper mantle

An earlier estimate by M. D. Crittenden of the effective viscosity of the upper mantle beneath the eastern Great Basin has been revised downward and improved in accuracy as a result of revisions in the chronology of Lake Bonneville, on the basis of data obtained by R. B. Morrison at Little Valley, Utah. The Bonneville overflow, originally assigned a date of about 45,000 years before present on the basis of a tentative correlation of glacial and lacustrine deposits, is now believed to have taken place a little less than 20,000 years ago. This value is based on detailed soil stratigraphy and is well supported by carbon-14 dating. Accordingly, the time constant of isostatic recovery, the time required for an anomaly to decrease to 1/e (1/2.718) of its initial value, is reduced to about the lower limit of the range deduced earlier (4,000 to 10,000 years). This, in turn, requires that the viscosity, originally assigned a range from $0.9\times10^{21}$ to $2\times10^{21}$ poises, must be near the lower limit of this range. This revision leaves little doubt that the effective viscosity in this area is a full order of magnitude lower than the value $10^{22}$ poises that has been obtained by many workers for Scandinavia. The difference is regarded as an expression of a fundamental difference in crustal character between the Basin and Range province and the Fennoscandian shield (Crittenden, 1–63).

### Geothermal investigations

Geothermal gradient and thermal conductivity studies by W. H. Diment and E. C. Robertson [79] indicate that the flow of heat from the interior of the earth at Oak Ridge, Tenn., is $0.73\pm0.04$ microcalories per $cm^2$ sec.

A. H. Lachenbruch, B. Vaughn Marshall, and John P. Kennelly, set up facilities to measure the flow of heat through the floor of the Arctic Ocean basin from the drifting ice station T-3. The first two casts were made in 3,790 meters of water at lat 82°45′ N., long 156° 30′ W. The measurements are in close agreement with each other, and preliminary evaluation of the data indicates a heat-flow value close to the worldwide average. The study is continuing.

Facilities for measuring earth heat flow in wells were set up in Menlo Park, Calif., by A. H. Lachenbruch, G. W. Greene, B. V. Marshall and J. P. Kennelly. Temperatures were measured in several wells in Nevada and

[79] Diment, W. H., and Robertson, E. C., 1963, Temperature, thermal conductivity, and heat flow in a drill hole near Oak Ridge, Tennessee; Jour. Geophys. Research. [In press]

California by Greene and by Robert Munroe; heat flow determinations and additional temperature measurements are underway.

### Electrical properties of the earth's crust

Deep resistivity soundings and magneto-telluric studies by G. V. Keller [80] indicate that the maximum resistivity in the crust is found at depths ranging from 5 to 15 km. In the New England–eastern New York area, the maximum resistivity is 200,000 ohm-meters or more. This resistivity is sufficiently great that audio-frequency electromagnetic signals could be transmitted through such rocks with only moderate loss. The resistivity begins to decrease markedly at depths ranging from 7 to 10 km, indicating either that the rocks at these depths contain a significant amount of water, perhaps several percent, or that temperatures at these depths are unusually high, over 700°C.

Similar studies in eastern Nebraska and along a traverse extending from Denver, Colo., to Barstow, Calif., indicate a maximum resistivity in the crust of at least 5,000 to 10,000 ohm-meters. Resistivity begins to decrease at depths ranging from 15 to 25 km.

### Structural interpretation of Arctic Ocean basin

Knowledge of the crustal constitution of the floor of the Arctic Ocean basin has been advanced by a study made by Elizabeth R. King and Isidore Zietz of aeromagnetic profiles furnished by the U.S. Coast and Geodetic Survey. The basin lies between the Eurasian and North American continents and is divided into two basins by the Lomonosov Range, a continuous submarine ridge 9,000 feet high. A significant contrast has been found between the relatively flat magnetic profiles on the Eurasian side of the range and the profiles on the Canadian side of the range that delineate a large area of intensely magnetic rocks. Although water depths in the major basin areas average 13,000 feet, about the same as other ocean areas, the areal extent of the deep water is reduced considerably by broad shelves off the surrounding continents. One of the unsolved problems of geology is whether the Arctic Ocean basin is oceanic with a thin basaltic crust as in the Atlantic and Pacific, or is formed by a sunken block of continental rocks as its geologic setting seems to indicate. Analyses of earthquake records have indicated that it is oceanic at least in the deeper parts. However, a comparison of the Arctic magnetic data with typical oceanic profiles for both Atlantic and Pacific Oceans shows that profiles on the Canadian side of the range are unlike the oceanic profiles, but they show a striking similarity to profiles over the Canadian shield and Precambrian platform areas of the continents. The profiles on the Eurasian side of the range, however, show a resemblance to the oceanic profiles. From this evidence it is concluded that the region of highly magnetic rocks is a large sunken block of continental material separated by the Lomonosov Range from the Eurasian basin, which may be oceanic.

[80] Keller, G. V., 1963, A program of research on the electrical properties of the earth's crust, with emphasis on the detection of underground nuclear explosions: U.S. Geol. Survey semiannual tech. summary report for the period July 1–Dec. 31, 1962. Open-file report.

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## THEORETICAL AND EXPERIMENTAL GEOPHYSICS

### Paleomagnetism

Completion of detailed paleomagnetic studies by R. R. Doell and A. V. Cox (1–63) on rocks from the island of Hawaii show that the anomalously low secular variation now present in the central Pacific area has existed since at least 1750. During earlier times there were also relatively long periods during which secular variation was very small; however, the paleomagnetic data clearly indicate a type of secular change with much longer periods than heretofore recognized.

Potassium-argon age determinations and paleomagnetic measurements have been completed on several Sierra Nevada igneous rocks for studies of geomagnetic field-reversal phenomena. Although many more determinations are required for a definitive statement, the data now available are consistent with polarity epochs of roughly equal duration and of the order of 1-million-years length.

### Stress waves in solids

P and S elastic wave velocities were determined by Louis Peselnick (1–62) in 24 samples of Solenhofen Limestone at atmospheric pressure and 25°C, with and without water saturation. The results were compared with single crystal constants of calcite and with the high-pressure data of Hughes and Cross.[81] The conclusions are:

1. Both P and S velocities in dry limestone are linear functions of the density.
2. Inhomogeneity of the limestone is small, resulting in less than 3-percent deviation of the P and S velocities from the least-square curves.
3. Extrapolation of the dry and saturated P and S velocities to the limiting density (density of calcite) shows that, as the porosity decreases, the behavior of the limestone can be interpreted as an aggregate of randomly oriented single crystals of calcite.
4. Water saturation of the limestones decrease both the P and S velocities.

The six elastic constants $C_{ij}$ of calcite were determined by the ultrasonic pulse-echo method by Louis

[81] Hughes, D. H., and Cross, J. H., 1951, Elastic wave velocities in rocks at high pressures and temperatures: Geophysics, v. 16, p. 577–593.

Peselnick and R. A. Robie (2–62). Robie reports that the linear and volumetric compressibilities of calcite calculated from these data agreed with Bridgman's static compressibility measurements within 4 percent.

### Rock deformation

Preferred orientation of mineral grains in a fine-grained rock can be studied by using an X-ray diffractometer and a suitable mechanism which scans a half-inch-diameter hemispherical end of a rock specimen. A device commonly used for this purpose was tested by E. C. Robertson and showed a built-in bias. A new design has been drawn up which eliminates the bias and makes the traversing automatic. It may be that a half-inch diameter gives insufficient grain population for the rather narrow X-ray beam, and that this can more easily be studied with the automatic scanner. Preliminary results from the initial mechanism indicate agreement with universal-stage results on marble, but the check is only fair.

Radiation by neutrons, protons, or X-rays damages the crystal structure of NaCl, lowering the rigidity and mechanical strength. Similarly, large plastic strain and cyclic deformation lower the density and hardness of NaCl. Extrapolated pressures from three sources on NaCl show that its molar volume at 1-bar pressure changes from 27.0 $cm^3$ at 0°C to 32.0 $cm^3$ at 800°C, and at 100,000-bars pressure the molar volume changes from 22.8 $cm^3$ at 0°C to 21.8 $cm^3$ at 800°C, revealing an apparently negative coefficient of expansion at high pressure.

A tabulation of porosity and bulk-density data of sedimentary rocks by G. E. Manger [82] indicates that the porosity of sandstone generally, but not invariably, decreases and the bulk density increases with depth of burial, age, degree of tectonic disturbance, and departure from homogeneous texture. The carbonate rocks show a much less sensitive variation in porosity and bulk density in relation to these factors. Pure shales show the most sensitive decrease in porosity and increase in bulk density with depth of burial and degree of tectonic disturbance.

T. H. McCulloh has studied the variations, with depth, or densities of sedimentary rocks. He reports that natural densities of nearly all sedimentary rocks converge with depth and age to a value between 2.6 and 2.7 g per $cm^3$. Thus, even for very young basins, variations in densities of sedimentary rocks cannot produce gravity anomalies below a limiting depth of about 10 km. When factors such as age, lithology, depth, and degree of alteration are constant, the porosity and density of rocks reflect depositional environment: nonmarine sediment is more dense than marine sediment, and deep-water marine sediment has the least density.

### Interpretation methods

Quantitative interpretation of aeromagnetic anomalies has been based for the most part on the use of physical models in which the direction of magnetization is parallel to that of the earth's field, although laboratory results show that this assumption is invalid for many rock units. Magnetic fields have been calculated by I. Zietz for inclinations of magnetization significantly different from the inclination of the earth's present field. The calculations are for a rectangular flat-topped mass with infinite vertical sides and a 75° inclination of the earth's field. Several significant empirical relationships between the physical model and the computed fields have been obtained. For low dips of magnetization the maximum and minimum points, rather than the points of inflection, mark the edges of the rock masses. The depth-calculation techniques described in Geological Society of America Memoir 47 are based on the assumption of induced polarization, but these same empirical rules can be applied equally well to the total intensity field when remanent magnetization is present. This probably explains the success of the Memoir methods when applied to observed aeromagnetic anomalies over sedimentary basins. For rock units having large remanent magnetization, the dip of the magnetization may be estimated from the ratio between the maximum and minimum anomaly amplitudes, and the declination may be approximated from the horizontal line between the locations of the extreme values. The method has been successfully applied to aeromagnetic data taken over volcanic buttes near the Bearpaw Mountains in Montana.

R. G. Henderson and Alphonso Wilson (report in preparation) have developed formulas for interpreting aeromagnetic anomalies caused by three-dimensional bodies of arbitrary shape. From the formulas, they have prepared interpretation charts for inclinations of 90°, 75°, 60°, 45°, 30°, 20°, and 0° and a graticule for an inclination of 75° for use with an optical analog computer.

B. F. Grossling has improved his computer program developed earlier for computing gravimetric and magnetic anomalies and directional derivatives for assumed bodies. A noteworthy innovation is an automatic optimizing routine which reduces to a minimum the number of elementary prisms of which the body is composed.

With the aid of a computer program developed by Victor Vacquier, R. G. Henderson and J. W. Allingham derived the remanent magnetism of the syenite and shonkinite layers of Square Butte laccolith, Montana, as well as the base contour from the aeromagnetic map

[82] Manger, G. Edward, 1963, Porosity and bulk density of sedimentary rocks: U.S. Geol. Survey Bull. 1144–E. [In press]

of the body. The shonkinite has a remanent vector with near-normal dip and strong west declination. The syenite remanent vector has negative dip and east declination. There was no evidence of reversed magnetization as found by Vacquier for the Round Butte laccolith about 2 miles west. Calculations in which the remanence has been so derived were first done by B.F. Grossling on seamounts. The work by Henderson and Allingham is the first application to a two-layered medium. It was reported at the symposium on computers in the mineral industry, Stanford University, June 1963.

In studies of theoretical aeromagnetic anomalies due to basement relief and intrabasement susceptibility contrasts of the same areal extent and amplitude, Henderson demonstrated that by downward continuation of the field the two cases can be readily distinguished. Surface-trend analyses in which polynomial surfaces of various degress were fitted by least squares to the suprabasement anomaly failed to yield residuals that revealed the uplift. He concludes from this and other evidence that analytical methods based on potential theory yield more useful information than those based on statistical theory.

A mathematical study of electrical resistivity methods by Irwin Roman gave the following results:

1. A symbolic notation permits the writing of the kernel function in the resistivity integral for a selected number of layers without knowing it for fewer layers.[83]

2. A method has been found for determining the surface potential for an earth with a selected number of horizontal layers when it is known for the case in which the number of distinct layers is one less.[84]

3. The truncation error in the quadrature of the integral involved in a resistivity problem can be used to reduce the number of subintervals needed in the mechanical evaluation of the integral.

A waveform-analysis technique was applied by W. A. Fischer to a series of terrain profiles of the Taira area, Japan. The parameters included (1) the mean and extreme altitudes of occurrence of geologic units; (2) the number of significant stream channels per unit length; (3) the gradients of valley walls, expressed in percent; and (4) the average depth of valleys, expressed in percent. The resulting analyses clearly demonstrate differences in landforms associated with various geologic unit and rock types.

Photometric analyses of a number of glacial features in Alaska were made by W. A. Fischer and T. M. Sousa, using densitometer curves derived from aerial photos. The curves indicate that relationships exist between the photo tone distribution and the type and relative ages of various glacial features, thus providing a possible method of differentiating glacial units.

[83] Roman, Irwin, 1963, The kernel function in the surface potential for a horizontally stratified earth: Geophysics. [In press]

[84] Roman, Irwin, 1959, An image analysis of multiple-layer resistivity problems: Geophysics, v. 24, p. 485–509.

### Infrared and ultraviolet investigations

W. A. Fischer reports that 3–5 micron wavelength imagery, made with an aerial infrared scanner, was obtained for part of Yellowstone National Park. It shows a large, low-level thermal anomaly over Gibbon Hill in the Norris Geyser Basin, which suggests that the underlying rocks may be younger than previously supposed. Thermal activity was also detected near Beaver Lake, in the north part of the basin, where such activity was not previously mapped.

Infrared aerial reconnaissance of parts of the island of Hawaii, led by W. A. Fischer and R. M. Moxham, was made with a solid-state detector that operates in the 3–5 micron and 8–14 micron regions. Along the east and southwest rift zones of Kilauea Volcano, thermal patterns were delineated that showed some previously unknown structural features and steam vents. Several large fresh-water springs, both cold and hot, were found to issue into the ocean in areas close to the shoreline. Because of the water-supply problems on the island of Hawaii, these springs may be of significant economic value.

Infrared imagery in the 3–5 and 8–14 micron regions was also obtained for part of the Shenandoah Valley, Va. The surveys were made by the University of Michigan Institute of Science and Technology with the cooperation of the U.S. Army Cold Regions Research and Engineering Laboratory. The Virginia Geological Survey participated with the U.S. Geological Survey in monitoring ground meteorological and radiometric conditions. Preliminary study of the imagery by S. J. Gawarecki indicates that the thermal-emission contrast between some rock types is greater than the visible-reflection contrast.

Laboratory experiments were performed with mobile ultraviolet imaging equipment at the Westinghouse Corporation laboratories, Baltimore, Md., by W. A. Fischer, S. J. Gawarecki, Reinhold Gerharz, R. M. Moxham, and Westinghouse personnel. It was found that the fluorescence of minerals can be detected on closed-circuit television even though the fluorescence cannot be seen with the unaided eye. This has been accomplished at distances of up to 25 feet from the photomultiplier receiver tube with a relatively low-power laboratory UV cathode-ray-tube transmitter, but this range no doubt could be increased with additional transmitter power. Supplemental experiments indicate that certain minerals may be differentiated on the basis of their phosphorescence-decay characteristics as displayed on the system's oscilloscope.

# GEOCHEMISTRY, MINERALOGY, AND PETROLOGY

## *FIELD STUDIES IN PETROLOGY AND GEOCHEMISTRY*

### STUDIES OF IGNEOUS ROCKS

C. P. Ross (Art. 82) has shown that the modal composition of the Idaho batholith may be slightly more calcic than previous estimates indicate. On the basis of 56 new and old modal analyses from various sources, the main inner facies of the batholith appears to be mainly granodiorite, whereas most published summaries indicate the main mass to be dominantly quartz monzonite. Ross further notes that (1) all diorite and quartz diorite analyses of samples are assigned to the calcic border zone, and (2) the batholith as now mapped includes rocks along the border that are distinctly more silicic than would be appreciated from the literature. As these calcic and silicic units of the outer parts of the batholith have not been observed in contact, their relation remains among the unsolved problems concerning the batholith. Of interest in this connection is the description by B. F. Leonard (1–63) of a syenite complex in the Big Creek quadrangle, Idaho, previously mapped as part of the batholith but now considered to be of Paleozoic age. Warren Hamilton (4–63) has described the relations of trondjemite rocks of the western border zone of the batholith in the Riggins quadrangle, Idaho.

As exemplified by the Canyon Mountain Complex in eastern Oregon (Art. 81), the magma stem that comprises alpine-type chromite-bearing peridotite and gabbro also includes soda-rich diorite and related rocks. Mapping by T.P. Thayer and others has shown that the peridotite and gabbro of the complex are characteristically alpine type. Intrusion of quartz diorite and extensive albitization of the kind described by James Gilluly near Sparta, Oreg., closely followed emplacement of the peridotite and gabbro. Similar relations have been found by Thayer and Van Vloten in West Pakistan, by Thayer in the Guleman district in Turkey, and have been described in detail in the Troodos Complex in Cyprus. The field relations in all of these complexes are incompatible with differentiation in place, but indicate a close magmatic tie between gabbro, diorite, and albitic metasomatism.

X-ray data for chemically analyzed olivines from the peridotite member of the Stillwater Complex, Montana, and olivines from alpine-type peridotites from northwestern California and southwestern Oregon have been combined by P. E. Hotz and E. D. Jackson (1–63) to construct a determinative curve for the range $Fo_{80-95}$. They conclude that the relation between the (062) spacing and Fo content is the same for olivines from both Stillwater and California–Oregon peridotites and that the determinative curve is probably valid for olivines from both stratiform and alpine-type environments.

F. S. Simons has discovered a new occurrence of a composite dike near Klondyke, Ariz. The dike, of probable Tertiary age, consists of a core of porphyritic rhyolite 15–20 feet thick with selvages of coarsely porphyritic andesite 1–2 feet thick. Field evidence indicates that the rhyolite intruded the andesite while the core of the original andesite dike was still hot and unconsolidated.

A preliminary petrographic study by J. T. O'Connor (Art. 15) of welded tuffs of the Piapi Canyon Formation at the Nevada Test Site has proved helpful in correlating stratigraphic units. The ratio of quartz: alkali feldspar: plagioclase phenocrysts is a particularly useful criterion. O'Connor notes that the phenocryst ratios change sharply within some cooling units and that mafic constituents commonly increase near the top of cooling units. The study indicates that some units originally mapped as Tiva Canyon member actually belong to the lower cooling unit of the Ranier Mesa Member.

C. S. Ross[65] has completed a study of the occurrence and character of microlites in silicic volcanic glasses and has shown that pyroxene is generally the most abundant and characteristic type. It occurs in two distinct forms, reflecting differences in genesis: (1) prismatic form, crystallized before emplacement, and (2) curved and segmented forms, crystallized after emplacement. He has noted that the hydrous ferromagnesians, amphibole and biotite, are rare as microlites. Other common microlites are sanidine and magnetite, the latter usually occurring only in small amounts.

Chevkinite (titanosilicate of lanthanum and cerium) reported by H. A. Powers as an accessory phenocryst in obsidian flows and thick ash flows of the Yellowstone Park region, and in some units of the Danforth tuff of south-central Oregon. This brings to four the number of regions of Cenozoic volcanism whose magmas are known to have produced chevkinite as an accessory phenocryst mineral. The previously known occurrences are the Bandelier Tuff of north-central New Mexico, and the Oak Spring Group in southern Nevada.

[65] Ross, C. S., 1962, Microlites in glassy volcanic rocks: Am. Mineralogist, v. 47, p. 723–740.

## STUDIES OF METAMORPHIC ROCKS

D. E. Lee, R. G. Coleman, and R. C. Erd,[80] on the basis of field and petrographic studies, have previously recognized three distinct types of glaucophane-bearing metamorphic rocks in the Cazadero area, California. Twenty-four new chemical analyses of garnets from the two garnet-bearing types of schist (designated III and IV) confirm the distinctions between types: the garnets from type III being almandine-spessartine-grossularite, and those from type IV being almandine-grossularite. These data disprove the notion, erroneously established in the literature on the basis of meager data, that garnets from glaucophane schists are typically poor in spessartine (Mn) and relatively rich in pyrope (Mg). Garnets in type-III schists are rich in spessartine (1 sample exceeds 60 molecular percent), and although garnets in type-IV rocks tend to contain more pyrope molecule than those in type-III rocks, they do not contain more than 13 molecular percent of pyrope.

P. K. Sims and D. J. Gable (Art. 10) have described the occurrence of cordierite in the Precambrian Idaho Springs Formation in the Central City quadrangle, Colorado. The cordierite occurs (1) with anthophyllite in lenses within a microcline-bearing granitic gneiss unit, and (2) with sillimanite and garnet in a biotitic gneiss unit. In both associations the cordierite evidently originated by dynamothermal metamorphism of argillaceous sedimentary rocks with little addition of material except possibly magnesium.

The generation of assemblages containing combinations of cordierite, pyropic garnet, pleonaste, sapphirine, staurolite, sillimanite, and corundum in pelitic xenoliths in the mafic igneous complex of Cortland, N.Y., has been described by Fred Barker.

Anna Hietanen has found that the calcium content of scapolite as well as plagioclase in the Precambrian Belt Series northwest of the Idaho batholith increases regularly with increasing grade of metamorphism and that this change is accompanied by systematic changes in the occurrence of the scapolite. In lower grade zones of the epidote-amphibolite facies, some distance from the batholith, scapolite occurs in layers reflecting beds in the original sedimentary rocks, whereas in higher grade zones it occurs irregularly or associated with faults and fissures. Still closer to the batholith it occurs as segregations in calcium-rich rocks, but within 10–15 miles of the batholith it is entirely absent. She attributes this distribution to the high mobility (volatility) of chlorine and the consequent migration of this constituent away from the inner contact zone. She further suggests that (1) the high mobility of chlorine may explain the absence of salt deposits in higher metamorphosed terrains, (2) metasomatic chlorine affecting scapolitization may originate from ancient salt deposits; and (3) the chlorine in granitic magmas generated by partial melting of sedimentary rocks may originate from saline beds.

A. E. J. Engel and Celeste G. Engle (1–63) have deduced that during progressive metamorphism in the Adirondaks, the loss of felsic elements from amphibolites began at about 600°C. At this temperature, alkalies, especially K, with Si, B, Rb, Cs, Ti, and Mn, were taken into solution by exsolved water and removed mechanically or by diffusion to cooler regions of the enveloping crust. Incipient melting of the rocks did not begin until 700°C or higher.

The Engels have further concluded on the basis of field mapping and regional stratigraphic synthesis that the Adirondak phacoliths are metasomatic in origin.

## STUDIES RELATED TO THE UPPER MANTLE

A large plug-shaped intrusion of peridotite at Twin Sisters Mountain in the Cascades of northern Washington is under study by G. A. Thompson as a possible sample of material from beneath the earth's crust. Gravity measurements reveal a positive anomaly of 29 mgal associated with the body and a gradient at the contacts of 10 to 20 mgal per mile. Since the density contrast of the peridotite with the surrounding rocks is 0.6 g per cc the depth extent of peridotite can be only about 4,000 feet, hardly more than the topographic relief on the body. Paradoxically, layers of chromite and pyroxene-bearing peridotite in the interior of the body generally dip steeply and thus suggest great depth extent. The most likely explanation is that the peridotite passes downward into serpentine with a density about equal to that of the country rocks. Similar results from preliminary measurements at several peridotite plugs in California suggest that an abundance of serpentine may be essential to the emplacement of these masses.

R. G. Coleman has made a study of New Zealand serpentinites and peridotites that form a great ultramafic belt extending from North Cape, North Island, to Bluff, the southern extremity of the South Island. Field evidence obtained shows that all the large New Zealand ultramafic masses form narrow restricted belts within the upper Paleozoic geosynclinal sediments and that a screen of serpentinite invariably separates the country rock from the unaltered ultramafites. Contained within these serpentinite screens are metasomatized tectonic inclusions of sedimentary and volcanic materials. Similar metasomatic alteration is occasion-

[80] Lee, D. E., Coleman, R. G., and Erd, R. C., 1963, Garnet types from the Cazadero area, California: Jour. Petrology. [In press]

ally developed at the serpentinite contact with these geosynclinal sediments and volcanic rocks.

The ubiquitous occurrence of such metasomatism indicates that the alteration is connected with the emplacement of the serpentinites. Hydrothermal experiments have shown that serpentinites and sediments react with one another at temperatures below 500°C and water pressures of 2,000 bars to form products similar to those seen in the metasomatic rocks. Field evidence also shows that the ultramafites were emplaced along major high-angle thrust faults. These faults are considered to be the mechanism whereby peridotites are transported upward from the mantle into the crust. This faulting developed along the weak zone represented by the volcanic rocks within the upper Paleozoic geosyncline deposits. In the early stages of faulting, when the ultramafites made initial contact with the wet geosynclinal sediments, serpentinization was initiated along with contact metasomatism. As the thrust faulting continued, large sedimentary inclusions became immersed in the serpentinite and also became metasomatically altered. Juxtaposition of peridotite mantle with geosynclincal sediments probably occurred at depths of 10–15 km with temperatures less than 500°C. No evidence was found to support the concept that these ultramafics were intruded as high-temperature magmas.

Studies by A. E. J. Engel and Celeste G. Engel of distribution coefficients of $Mg/(Mg+Fe^{+2})$ in coexisting pyroxenes of metamorphic and igneous rocks indicate separable values which are in large part temperature dependent. From the existing data, approximate temperatures of formation may be deduced for pyroxenites, pyroxene gneisses, gabbros, basalts, and other mafic rocks and possibly meteorites.

## ACTIVITIES OF THE HAWAIIAN VOLCANO OBSERVATORY

Following the flank eruption on the east rift zone of Kilauea in September 1961, tiltmeters indicated a resumption of inflation of the summit of the volcano resulting from magma from depth refilling the reservoir under the summit which had been rapidly drained during the September outbreak. This gradual inflation continued for more than 14 months until early December 1962, at which time the level of inflation was only slightly below the level which preceded the September 1961 eruption.

The first indication of possible activity was the onset of nearly continuous harmonic tremor at 7:30 p.m., December 6. At 1:10 a.m., December 7, a line of lava fountains broke out on the floor of Aloi Crater on the east rift zone 5 miles from the summit of Kilauea. A lava lake 45 feet deep formed, but rapid drainback left only a crust up to 15 feet thick on the floor of the crater. In the next 2 days, 6 more outbreaks occurred in a line on the rift zone extending from Aloi Crater 2½ miles toward the east. Preliminary measurements of volume indicate that approximately 120,000 cubic yards of new lava remains on the surface and covers an area of 16 acres.

### Kilauea Iki lava lake

In October 1961 a hole was drilled through the 35-foot crust on Kilauea Iki lava lake, and a hollow stainless steel–mullite probe containing a thermocouple was forced 4 feet into the underlying melt. Observations made by W. U. Ault, D. H. Richter, and D. B. Stewart (1–62) during emplacement of the probe permit the base of the crust to be identified as the 1065°C isotherm. The maximum temperature measured in the molten lava was 1106°C. The thermal gradient in the liquid was 5°C per foot, and the cooling rate for a 22-day period was 0.5°C per day at a depth of 39.2 feet. After the first 8.1 months, the average rate of crustal thickening for a 13.3-month period was 0.94 foot per month.

In January 1963 a new hole was drilled through the crust of the lava lake and a 5-foot all-ceramic probe was forced into the melt to a depth of 48 feet from the surface. On January 23, the crust was 45.0 feet thick, and the temperature 3 feet below the crust was 1087°C. By early February, the hole was still open and temperature profiles were being measured weekly.

### Lava tree molds

One of the interesting secondary phenomena of the 1961 flank eruption of Kilauea volcano was the formation of abundant lava tree molds. These remarkable upright tubes described by J. G. Moore and D. H. Richter (1–62) were produced where the extremely fluid lava, flowing through dense tropical forest, became chilled in contact with the larger trees and the remaining fluid lava drained away. The feature displayed by these new molds lead to a clearer understanding of the mode of formation of the abundant prehistoric tree molds in Hawaii. Where the lava ponded temporarily in a structural valley, tree molds more than 14 feet high mark the high level attained by the flow. Then as the lava drained away downslope and into cracks, the crust which had formed on the surface of the lava was lowered around the tree molds, which now protrude above the crust.

### Halogen gases

Analysis of fumarolic gases by K. J. Murata, W. U. Ault, and D. E. White from the degassing lavas of the 1959–60 Kilauea eruption indicates that halogen acids can be important fugitive constituents of basaltic magmas and are not restricted to more siliceous magmas. Steam condensates from the hottest 1959–60 vents contained as much as 1.1 N HF and 2.0 N HCl.

## GEOCHEMISTRY OF HOT SPRINGS AND THERMAL AREAS

D. E. White, E. T. Anderson, and D. K. Grubbs (1–63) have published an account of the discovery during exploratory drilling for geothermal steam power near Salton Sea, Calif., of a hot saline brine with extraordinary characteristics. The brine at a depth of 5,000 feet has a temperature of 300°C, and contains an exceedingly high concentration of potassium (24,000 ppm) as well as appreciable concentrations of lithium, rubidium, silver, copper, lead, zinc, manganese, strontium, and probably other elements. Thus, the discovery is attracting great economic as well as scientific interest. The brine may be connate in origin, but present evidence favors a source in a magma chamber at depth that supplied the late Quaternary rhyolite domes in the area. With its high content of metals the brine may be man's first sample of an active ore solution.

R. O. Fournier investigated a recently formed hot spring in Yellowstone National Park and found that it is depositing silica at rate a hundred times faster than any other known hot spring in the region. The silica which is being deposited is a mixture of poorly crystalline material (probably cristobalite) and quartz (or chalcedony).

D. E. White and G. E. Sigvaldason (4–63), prompted by the recent identification of epidote in hot-spring systems in Kamchatka, New Zealand, and in Iceland, have discussed the origin and stability of epidote in hydrothermal and metamorphic environments. By analogy with the effect of partial water pressure versus total pressure in the analcite-albite reaction, they suggest that epidote is stable in hot spring environments and tentatively define limits of depth and temperature for the formation of epidote in such environments.

Sigvaldason and White (1–62) have further added to the information on alteration in hydrothermal areas, in their description of mineralogical changes in two drill holes at Steamboat Springs, Nev.

As part of a study of the geology near Soda Springs, Idaho, Frank C. Armstrong collected samples of the water and gas from a few of the large springs of $CO_2$-charged water in the area. The low boron, nitrogen, chloride, and alkali-metal contents found on analysis of the water suggest that no water of magmatic, metamorphic, or connate origin is contributed to the springs from depth. If any such waters are present, they are added to the springs in such small amounts that they cannot be recognized in the flood of meteoric water. A deep source for most of the $CO_2$ is suggested, however, by the large quantities of that constituent in the springs. Isotopic analyses of the $CO_2$ by Irving Friedman show that the $C^{13}/C^{12}$ ratio of the gas is similar to that of marine carbonate rocks. Paleozoic marine limestones and dolomites thousands of feet thick crop out in the mountains near Soda Springs. Thus the $CO_2$ of the springs is thought to be derived from the breakdown of marine carbonate rocks. The widespread presence of late Pleistocene volcanic activity in the area suggests that residual heat from the volcanism may decompose carbonate rocks at depth and thereby contribute large quantities of $CO_2$ to the springs.

Physical and chemical controls on distribution of radium and radon in ground water have been studied in two areas near Great Salt Lake, Utah. A. B. Tanner measured the concentrations of radium, radon, and chemical constituents affecting iron equilibria in waters from wells both near and distant from subsurface faults. He concludes that either the variation in quality of water or the influx of thermal water from faults may determine radium distribution, but that radon concentration is more likely to be related to the influx of thermal waters.

## STUDIES OF SEDIMENTARY ROCKS AND DIAGENETIC PROCESSES

Unusually pure unctuous clay beds, 1 to 6 inches thick, in the Jurassic Carmel Formation in southwestern Utah have been identified as bentonites by L. G. Schultz and J. C. Wright (1–63). Although the clay matrices of the bentonites are variable mixtures of kaolinite, illite, several types of mixed-layer clay, and relatively little montmorillonite, the ubiquitious distribution of small amounts of euhedral sanidine and biotite demonstrates a volcanic origin and suggests derivation of the clays from a tuff of uniform composition. A further discussion of nonmontmorillonitic bentonites has been published by Schultz (2–63). The conspicuous variation in clay mineralogy of the bentonites is attributed to postdepositional alteration governed by environmental factors such as variations in oxidation and in salinity of connate water during diagenesis.

Electron microscope studies of Florida clays by E. J. Dwornik with Z. S. Altschuler[87] have corroborated field, X-ray, and chemical data in documenting the transformation of montmorillonite to kaolinite over widespread areas in Florida. In the Bone Valley Formation the kaolin zone is several feet thick over hundreds of square miles. Micrographs clearly depict incipient kaolinization as hexagonal modification of the

[87] Z. S. Altschuler, E. J. Dwornik, and Henry Kramer, 1963, Transformation of montmorillonite to kaolinite during weathering: Science, v. 141, no. 3576, p. 148–152.

edges of montmorillonite plates. Ultimately completely kaolinized aggregates are formed.

H. A. Tourtelot has discovered that tiny green pellets, of a type commonly called glauconite, occurring in a clay bed at the base of the Fox Hills Sandstone near Red Bird, Wyo., consist of a completely mixed-layer clay mineral. They are enclosed in a matrix consisting of a mixture of illite, montmorillonite, mixed-layer illite-montmorillonite, and small amounts of kaolinite and chlorite. The pellets are morphologically similar to fecal pellets found elsewhere in the Pierre Shale, and since they are the largest discrete grains in the rock, they appear not to have been transported from a distant source. The difference in composition of the pellets and matrix is apparently the result of reactions controlled by the biological history of the pellets and the chemical and physical characteristics of the depositional environment.

W. A. Braddock and C. G. Bowles (Arts. 83 and 84) have described breccia pipes, "sills," and sinks in the Minnelusa Formation of Pennsylvanian and Permian age in the Black Hills, that they attribute to solution and removal of as much as 250 feet of anhydrite beds by ground water. In the zone of removal, the remaining rocks have been oxidized; dolomite and anhydrite cements of sandstones have been replaced by calcite; and bedded dolomites have been converted to limestones. The process apparently began in early Tertiary time and, from the evidence of ground water compositions, appears to be continuing in the present.

Recent studies by Cadigan [88] of grain-size distribution in continental sedimentary rocks of the Colorado Plateau provide a scheme for tectonic interpretation as follows: grain size varies directly with the rate of tectonic uplift in source areas, and degree of sorting varies inversely with the rate of tectonic subsidence in the area of deposition. From such data a graphic representation of the interaction between rate of uplift and rate of subsidence in the two areas may be developed for use in geologic interpretations. A correlation graph based on these concepts is the subject of work now being completed by Cadigan.

A study of the Triassic Chinle Formation by Cadigan (Art. 14) shows the sandstones to be sodic arkoses and feldspathic tuffs. Average sorting and average mean grain size suggest that the sediments were derived from source areas undergoing uplift at a moderate rate, and were deposited in an area that subsided at a moderate rate. Average skewness and kurtosis indicate low to moderate reworking and transportation.

[88] Cadigan, R. A., 1961, Geologic interpretation of grain-size distribution measurements of Colorado Plateau sedimentary rocks: Jour. Geology, v. 69, no. 2, p. 121–144.

Study by P. L. Williams of altered Entrada Sandstone in the Moab 2° quadrangle, Colorado and Utah, indicates that alteration in the Entrada Sandstone is closely related to the rock color, and that vanadium and uranium mineralization in the Entrada is restricted to altered sandstone characterized by white, gray, or pale-yellow color. The amount of carbonate cement varies over a wide range in the two upper members of the Entrada but on the average is as abundant in altered as in unaltered sandstone. It is, however, only half as abundant in the Moab Sandstone Member as in the Slick Rock Member, whether or not the rock is altered. This probably accounts for the greater permeability, hence the more extensive alteration of the Moab Member.

## MINERALOGIC STUDIES AND CRYSTAL CHEMISTRY

David R. Wones (2–63) investigated variations in the indices of refraction and unit-cell dimensions of biotites. Regression equations relating

$$\frac{Fe}{Fe+Mg}$$

ratios to the physical properties demonstrate systematic variations with changing oxygen pressure and temperature. These studies indicate that biotites may be used as "oxygen barometers", independently of the reaction assemblage, provided the effects of other common substitutions such as Na, Ti, Al and Fe are understood.

The trace-element content of serpentines has been investigated by G. T. Faust,[89] who has demonstrated that serpentines derived from ultrabasic rocks, such as those of Snarum, Norway; Staten Island, N.Y.; and the Eden and Lovell areas of Vermont, are relatively high in Ni, Cr, Co, and Sc content, while those related to hydrothermal deposits, such as those at Cornwall, Pa., are low in these elements.

X-ray diffraction studies of natural palygorskite samples, by J. C. Hathaway and P. B. Hostetler, have turned up two new polytypes, both with primitive orthorhombic unit cells.

D. B. Stewart demonstrated that at 700°C and 2 Kb (kilobars) the use of gels or glasses of the same composition for the starting materials had no effect on the structural state ultimately attained by albite that crystallized from these materials, although albite that formed from gel reacted approximately 8 times faster. These results indicate that the structural state attained

[89] Faust, G. T., 1963, Minor elements in serpentine—additional data: Geochim. et Cosmochim. Acta. [In press]

is probably the equilibrium value for the condition. Albite that crystallized from material containing either $SiO_2$ or $LiAlSiO_4$ has a higher structural state than albite synthesized from material containing $NaAlSi_3O_8$ alone. These laboratory results are significant because they can be applied to the interpretation of the structural state of feldspars found in rocks.

Because their equilibrium compositions are sensitive indicators of metamorphic grade, the paragonite-muscovite mica pair is useful for the study of aluminous schists. E-an Zen has assembled and measured data on the basal spacings of 44 such mineral pairs. The data are readily fitted to a straight line. Use of this line will give minimal estimates of the metamorphic grades of rocks in which only one of the two white micas occurs.

An interesting quartz-kyanite vein in an eclogite from Zermatt, Switzerland, containing two paragonites with different ratios of sodium : potassium has been studied by E-an Zen. The high-potassium paragonite is intimately associated with muscovite. The petrologic relations, as explained by Zen, are due to metastable equilibrium crystallization followed by annealing. The process seems sound theoretically and may be of broader applicability in nature than in this single instance.

Members of the isostructural ludwigite-vonsenite series of anhydrous borates resemble the hydroxyl-bearing silicate ilvaite in habit, color, luster, density, and qualitative optical properties. Suitable means of recognizing and identifying these minerals are desirable, as they differ in economic, petrologic, and geochemical significance. Leonard, Hildebrand, and Vlisidis (1–62) investigated 2 ludwigites, 2 vonsenites, and 2 ilvaites by chemical, spectrochemical, X-ray, and optical methods. They found that the ilvaites differ from the ludwigites and vonsenites in (1) crystallographic orientation of reflection-pleochroism and complex indicatrix of reflectivity, (2) effect of oil immersion on reflection-pleochroism, (3) reflectivity in air and oil, and (4) bireflectance and its dispersion. Other physical properties, such as nonmagnetic character and behavior in transmitted light, are helpful in distinguishing ilvaite from most members of the ludwigite-vonsenite series, but X-ray powder data and optical properties in reflected light are generally more useful.

The initial study of melanophlogite has been completed by B. J. Skinner and D. E. Appleman[90] (1–63) who have verified that it is, indeed, a cubic polymorph of silica less dense than silica glass. The hydrogen, carbon, and sulfur appearing in analyses are present in organic films trapped on the cubic growth surfaces of the compound. The organic and sulfur materials are therefore physically incorporated inclusions and are not integral parts of the structure. Although melanophlogite is quite stable up to 1000°C for many days, even gentle grinding at room temperature causes it to invert to quartz, a more dense and presumably more stable form of $SiO_2$, at 1 atmosphere pressure.

The unusual silica polymorph stishovite, which has Si in 6-fold coordination with oxygen as compared with the usual 4-fold coordination of all the other polymorphs, has been extensively studied by B. J. Skinner and J. J. Fahey[91] (2–63). This strange compound, reported only from Meteor Crater, Ariz., and the Ries Crater in Bavaria, breaks down to silica glass at measurable rates at temperatures as low as 300°C. The breakdown rate was measured at 10 temperatures between 300° and 800°C, and it was demonstrated that for an isothermal breakdown, the concentration of the stishovite remaining is a linear function of the heating time. The time for total decay of stishovite to silica glass at each temperature provides a time-temperature curve which limits any thermal-distribution model proposed for Meteor Crater. The relative instability of stishovite also demonstrates that it is practically impossible for it to be quenched in any normal geologic environment, even though the necessary high pressures for its formation have been reached. Thus, the presence of stishovite on the surface of the earth is even more compelling evidence for an origin by meteoritic impact than is the presence of coesite.

Other important silicate minerals have been studied for various reasons. The scapolites have been extensively investigated by H. P. Eugster, H. J. Prostka, and D. E. Appleman (1–62, 1–63), whose analysis of the changes in cell constants with varying composition between the end-member compounds marialite, $3NaAlSi_3O_8.NaCl$, and meionite, $3CaAl_2Si_2O_8.CaCO_3$ has thrown considerable light on the phase changes occurring in systems. The zeolites clinoptilolite and heulandite were examined by D. E. Appleman and D. B. Stewart. The crystallography of these very similar compounds was satisfactorily delineated, allowing better detection methods to be devised, particularly for the clay-sized material in which the zeolites commonly occur. From a study of the twinning and structural disorder among crystals from several localities, M. Ross found that stilpnomelane has a large super cell based on a prominent rhombohedral subcell.

A thermal and X-ray study of natural and synthetic leucites, by G. T. Faust (1–63), demonstrates that they

[90] Skinner, B. J., and Appleman, D. E., 1963, Melanophlogite, a cubic polymorph of silica: Am. Mineralogist. [In press]

[91] Skinner, B. J., and Fahey, J. J., 1963, Observations on the inversion of stishovite to silica glass: Jour. Geophys. Research. [In press]

undergo a complex reversible phase transition between 614° and 669°C. Synthetic iron leucites, however, have a simple reversible transition, with an endothermic reaction, at a sharply defined temperature of 550°C.

Marie L. Lindberg has studied the corvusite group of minerals, the vanadyl polyvanadates, which are divided into monoclinic and orthorhombic modifications. Both modifications are found at the Monument No. 2 mine, on the Navajo Indian Reservation, Apache County, Ariz.

In extending previous extensive mineralogical studies of the phosphate minerals, M. E. Mrose has carried out crystal-chemistry investigations on azovskite, $Fe_3(PO_4)_2(OH)_3.2\frac{1}{2}H_2O$, by comparing material from a new locality in Greenbelt, Md., with that from the type locality on the Taman Peninsula, in the Sea of Azov in Russia. The isostructural pair, mitridatite, $Ca_3Fe_4(PO_4)_4(OH)_6.4H_2O$, from North Grafton, N.H., and arseniosiderite, $Ca_3Fe_4(AsO_4)_4(OH)_6.4H_2O$ from Romaneche, France, have been compared, and the isostructural relation between montgomeryite $Ca_4Al_5(PO_4).(OH)_5.11H_2O$ from Fairchild, Utah, and calcioferrite, $Ca_4Fe_4(PO_4)_6(OH)_5.11H_2O$, from Battenberg, Bavaria, has been demonstrated.

R. A. Gulbrandsen and others discovered leucophosphite and apatitized wood in nodules from the Moreno Formation, California, a new locality for leucophosphite (Art. 85).

In the continuing borate mineral investigations, the results of the comprehensive refinement of the calcium borate hydrate series, $2CaO.3B_2O_3.nH_2O$, with n=1 (synthetic compound), 5 (colemanite), 7 (meyerhofferite), 9 (synthetic compound) and 13 (inyoite), have been completely analysed and interpreted by J. R. Clark, D. E. Appleman, and C. L. Christ. A computer program has yielded a complete list of all interatomic distances and bond angles for all five structures, which have been used to define the basic principles underlying the boron-oxygen configurations and distances, cation coordinations, and hydrogen-bond system.

Mineralogic studies by M. E. Mrose and M. Fleischer have shown that magnioborite and suanite are the same compound, $Mg_2B_2O_5$, which is a monoclinic polymorph triclinic compound synthesized in the laboratory.

The mineral koutekite, supposedly $Cu_2As$, has been shown to have the formula $Cu_5As_2$ by B. J. Skinner. The high-temperature phase relations in the system Cu-As have been elucidated by use of the electron-microprobe analyzer, and coexisting phases in both natural and synthetic mixtures of copper arsenides have been analyzed. This has led to a good understanding of the phase relations and mineralogy of the Cu-As system and has shown that the high- and low-temperature data are quite compatable. Structural studies of $\beta$-domeykite ($Cu_3As$), by M. Ross have shown that the previously published structure is in error, and that $\beta$-$Cu_3As$ is isostructural with fluocerite $CeF_3$, for which the published structural data are also in error. Structural studies are proceeding on $Cu_5As_2$.

The identity of the new copper sulfide djurleite, $Cu_{1.96}S$, has been firmly established by E. H. Roseboom (1–62) and D. E. Appleman, who separated single crystals from natural specimens and derived an orthorhombic cell by X-ray diffraction techniques. The cell is closely similar to chalcocite and contains approximately 128 formula units.

The puzzling compound valleriite has been the object of an intensive study by H. T. Evans, R. A. Berner, and C. Milton (1–63). The crystallography is similar to the previously described mineral smythite, $Fe_3S_4$, and indicates a formula of $CuFeS_2$, polymorphic with chalcopyrite. Its intimate oriented-interlayer association with a magnesium-aluminum hydroxide phase has been clearly demonstrated by X-ray diffraction. These results, combined with the electron microprobe investigations of I. Adler, have cleared up the long-standing confusion between valleriite, a rare mineral, and the recently recognized mackinawite, FeS, a common polymorph of pyrrhotite.

## EXPERIMENTAL GEOCHEMISTRY

The solubility of quartz in steam at high temperatures and pressures was determined by D. B. Stewart by equilibrating a series of accurately weighed amounts of crystals and water in a sealed capsule and examining the quenched products for the presence of crystals, which indicate that the solubility has not been exceeded. The method has the significant advantages that the equilibrium value can be approached from either the gas or gas-plus-crystal fields, that temperature gradients are less bothersome, and that a number of experiments can be conducted simultaneously in a single pressure vessel. The solubility at 2Kb at 700°C is $0.94\pm0.05$ weight percent and is $1.40\pm0.04$ at 800°. At 700°C and 4 Kb the solubility is $2.0\pm0.05$ weight percent. The solubility increases with either increasing temperature or pressure.

R. O. Fournier and J. J. Rowe measured the solubility of chalcedony in liquid water in the presence of gaseous water at temperatures up to 250°C. At 250°C the solubility is 523 ppm and at 125°C it is 124 ppm. The extrapolated solubility at 25°C is 17 ppm. The heat of solution is 4.84 kcal per mole. The data indicate that a chalcedonic phase, distinguishable from quartz, is not likely to form or persist in nature above about 265°C.

The solubility of quartz in aqueous solutions at elevated temperatures and pressures as a function of HCl and alkali chloride content at moderate acidities is being investigated by J. J. Hemley. Solubilities in the electrolyte solutions have not been fully evaluated, but the effects on solubility are small. Work has been continued in the systems $Na_2O$–$Al_2O_3$–$SiO_2$–$H_2O$ and $K_2O$–$Al_2O_3$–$SiO_2$–$H_2O$ with emphasis on the role of aqueous silica concentration in defining stability relations between minerals. Previous experimentation has been concerned primarily with mineral equilibria as defined by the alkali-ion/$H^{+1}$ ratio in systems in equilibrium with quartz. Undersaturation or supersaturation with respect to quartz has an important effect on reactions and equilibria in these systems. Equilibria of interest include, for example, the decomposition of kaolinite to alumina hydrate (bauxite minerals) and the relation of muscovite to montmorillonite-type phases.

A new method for the determination of the concentration of $Na^{+1}$ in aqueous solutions of varying degree of concentration was developed by A. H. Truesdell. The $Na^{+1}$ activity of a solution is determined in the solution accurately diluted to an ionic strength less than 0.01, using a sodium-sensitive glass electrode. At this ionic strength the Debye-Huckel relation applies, so that the concentration can be accurately calculated from the measured activity. If the dilution factor is known, the concentration in the original solution can be calculated. Preliminary results indicate an accuracy of ±0.5 percent of the amount present, compared with ±1 to 2 percent for flame-photometer determinations.

The solubilities of some sodium salts determined electrometrically are (expressed as grams of anhydrous salt per 100 g saturated solution):

| | 25°C | 40°C |
|---|---|---|
| NaCl | 36.05 (36.15)[1] | ----------- |
| $Na_2B_4O_7 \cdot XH_2O$ | 3.08 [2] (3.06) | 5.86 [2] (5.9) |
| $NaCaB_5O_9\ XH_2O$ | 0.55 | ----------- |

[1] Values in parentheses are literature values.
[2] In equilibrium with borax.

Herbert R. Shaw (1–63) has developed an experimental technique which permits the simultaneous control and measurement of the partial pressure of hydrogen, oxygen and $H_2O$ at pressures and temperatures of petrologic interest. This is accomplished by externally controlled diffusion of hydrogen through metallic membranes contained within a pressure vessel. The technique is exceedingly valuable for studying high-temperature–high-pressure reactions where different oxidation states of iron are involved.

The viscosity of a hydrous silicate melt approximating the composition of some granitic magmas under plutonic conditions was determined by H.R. Shaw.[92] Samples of natural glass (obsidian) were hydrated at 800°C and 2,000 bars total pressure, which produces a homogeneous hydrous liquid containing approximately 6 weight percent $H_2O$. The viscosity of this liquid was determined by the classical falling-sphere method, using platinum and silver spheres. The logarithm of the viscosity (poises) calculated from Stokes law, without minor corrections for geometrical properties of the containers, is given by

$$\log_{10}\eta = 5.6 \pm 0.1$$

This viscosity is more than four orders of magnitude lower than that for melts of similar composition but with little $H_2O$.

The reciprocal salt systems are under continued study by G. Morey and others.[93] The binary join $K_2SO_4 \cdot 2MgSO_4$ (langbeinite)–$K_2SO_4 \cdot 2CaSO_4$ (calcium langbeinite) is not a binary system because calcium langbeinite melts incongruently at 1013°C to form $CaSO_4$ and a liquid richer in $K_2SO_4$. The field of $CaSO_4$ extends over the join to about 43 percent calcium langbeinite, and at lower temperatures there is a complete series of solid solutions.

D. B. Stewart has found that minute synthetic crystals of quartz, grown in the laboratory under very high pressure and temperature from compositions in the system anorthite–silica–water, contain fluid inclusions whose spatial distribution throughout the crystal is controlled by and is indicative of the crystal symmetry of the quartz phase (high-hexagonal, or low-rhombohedral) that was present at the conditions in the bomb. The inclusions also present some useful data on the fluid-phase relations inside the bomb, as they represent minute samples of the fluid from which the crystals grew. Examination by Edwin Roedder reveals that several phase changes have occurred in these fluid inclusions on changing from the conditions of trapping (up to 10,000 atmospheres pressure and up to 975°C) to room conditions. Some of them have separated into a globule of a highly aqueous phase and a silicate melt at one temperature during the cooling, and then at some presumably lower temperature the aqueous phase has separated into two additional fluid phases, a low-density (vapor) bubble and a liquid (water) solution.

Edwin Roedder has found a series of interesting and useful phenomena with the microscope freezing stage. Drastic supercooling is almost aways observed on cooling the inclusions; many will remain as supercooled

[92] Shaw, H. R., 1963, Obsidian–$H_2O$—viscosities at 1,000 and 2,000 bars in the temperature range 700°–900°C: Jour. Petrology. [In press]

[93] Morey, G. W., Rove, J. J., and Fournier, R. O., 1963, The system $K_2Mg_2(SO_4)_3$ (langbeinite)—$K_2Ca_2(SO_4)_3$ (calcium langbeinite): Jour. Inorganic Chemistry. [In press]

(metastable) liquid water solutions for 30 minutes or even many hours at 50°C or more below their true freezing temperature. Exceptional inclusions may stay thus as supercooled liquids for weeks. This phenomenon suggests that all possible extraneous nuclei for the crystallization of ice have been removed from these fluids by geologic processes (solution, settling, and filtration) prior to trapping. Ordinary surface waters can only be supercooled a few degrees. The supercooling found for these inclusion fluids is far more extensive than has been reported in the literature on the supercooling of very pure water samples in laboratory vessels.

Edwin Roedder, in collaboration with R. L. Smith and others, has examined the gas bubbles in a wide variety of vesicular glasses and other volcanic materials. The method used is an adaptation of a technique originally proposed by George Deicha of Paris, and involves crushing in oil under the microscope. If the gas in the bubble is under a pressure greater than atmospheric, it will expand on crushing; if less, it will shrink. The samples examined included vesicles in obsidians, tachylytes, vitrophyres, and pumices; the odd hollow glass "bubbles" found in certain volcanic air-fall material and ocean sediments; and the exceedingly minute bubbles in the glass inclusions in phenocrysts from lavas. Although many of these have 1-atmosphere gas pressure in them (presumably air which has leaked in), most samples show at least a few vesicles with almost a complete vacuum. This is found to be true even for samples of Miocene age. As the walls of some of these vesicles are only 10 microns thick, the results appear to indicate fantastically low diffusion rates for air through these natural glasses.

E. H. Roseboom has completed his investigation of the Cu–S system by means of high-temperature X-ray techniques. The new mineral djurleite ($Cu_{1.96}S$) was synthesized at room temperature and pressure. Both synthetic and natural djurleite were observed to break down reversibly at about 90°C to a mixture of chalcocite and djurleite. The tetragonal form of $Cu_{1.96}S$ which inevitably forms along with djurleite when synthesis is carried out dry at 200°C or higher has been shown to have no stability field and thus far has not been observed in nature. The amount of the tetragonal form that appears at any temperature is a function of both the temperature investigated and the maximum temperature to which the specimen was previously heated.

D. B. Stewart demonstrated that the gaseous $H_2O$-rich phase that coexists with lithium aluminum silicates at 2 Kb is siliceous and that the solubility of silicates in this phase is many times the solubility of quartz in pure $H_2O$ under the same pressure and temperature conditions.

## GEOCHEMICAL DATA

Six chapters of the "Data of Geochemistry" were published during the year. They are as follows: chapter F, "Chemical Composition of Subsurface Waters," by D. E. White, J. D. Hem, and G. A. Waring (2–63); chapter G, "Chemical Composition of Rivers and Lakes," by D. A. Livingstone (1–63); chapter K, "Volcanic Emanations," by D. E. White and G. A. Waring (3–63); chapter S, "Chemical Composition of Sandstones—Excluding Carbonate and Volcanic Sands," by F. T. Pettijohn (1–63); chapter T, "Nondetrital Silicious Sediments," by E. R. Cressman (1–62); and chapter Y, "Marine Evaporites," by F. H. Stewart (1–63). Thirty other chapters are in varying stages of completion.

Tom G. Lovering has continued a study of the feasibility of coding and retrieving geologic and geochemical data by machine. Data for several thousand samples have so far been put into the system, and various types of trial retrievals have been made.

Tom Wright and Michael Fleischer completed a review of data of the geochemistry and mineralogy of the platinum metals. The metals are concentrated mainly in ultrabasic rocks and sulfide ores. Data on the platinum-metal content of other types of rocks are inadequate.

Tom Wright has assembled available data on the mineralogy and geochemistry of lithium, and finds that the lithium content of minerals of differentiated suites tends to increase in successively later members. Biotite and muscovite are the principal concentrators of lithium, but hornblende, feldspar, and quartz may also contain considerable amounts of lithium. The metal is usually mobile in contact aureoles and is enriched in pneumatolytic deposits (greisens), but it shows no distinct pattern of behavior in regionally metamorphosed rocks. Lithium is distinctly concentrated in clays and shales and in the clay fraction of other sedimentary rocks, and it also occurs in brines, volcanic hot springs, and saline deposits; its content is low in meteorites and tektites.

H. W. Lakin and others studied the variation of minor-element content of 12 samples of desert varnish from Death Valley, Calif., and northeastern Nevada (Art. 8). Possibly significant correlations were recognized between high boron content of varnish and the high-boron province of Death Valley, and high copper content of varnish and the high-copper subprovince of the Antler Peak-Copper Basin area, Nevada. Cobalt, barium, lanthanum, molybdenum, nickel, lead, and yttrium correlate with manganese content. Thus the content of these elements in varnish is probably of no practical use in geochemical prospecting techniques aimed at delineating mineral deposits.

A. J. Bartel and others (Art. 6) studied the arsenic content of 48 samples of basalt from California, Connecticut, Hawaii, Idaho, New Mexico, and Oregon. Comparison of the results of this work with 66 arsenic determinations for similar rocks and diabase published by other workers indicates that the median arsenic content for basalt and diabase is probably 1 ppm.

J. S. Vhay reports that almost all sedimentary rocks containing manganese also contain cobalt, regardless of whether the manganese is disseminated in small amounts or occurs in high concentrations in nodules. During weathering of the rocks, especially under alkaline conditions, the manganese is immobile and retains the cobalt.

## GEOCHEMISTRY OF WATER

Investigations of the geochemistry of water by the U.S. Geological Survey are directed mainly toward explaining the relations of the chemical content of natural water to the hydrologic and geologic environment. Some of the diverse topics under study include the source of dissolved mineral content of precipitation, the relation of mineral content of streams to the geology of the drainage basins, the relation of the chemistry of ground water to that of the containing deposits, sources of mineral matter in ground water, and the application of geochemistry to solving problems in subsurface geology and hydrology. In addition, theoretical and experimental studies are made to explain by chemical thermodynamics the chemical reactions between water and earth materials.

### STUDIES OF ATMOSPHERIC MOISTURE

#### Mineral content of precipitation

In the summer of 1962 a network of precipitation-sampling stations was set up covering five major drainage basins of North Carolina and Virginia. Preliminary results reported by Arlo Gambell (Art. 114) suggest that the atmosphere is a major source of the dissolved solids in the streams draining the area. The average $SO_4^{-2}$ concentration of precipitation collected during the first month of operation was almost 3 ppm compared with 5 to 9 ppm in the stream waters. Significant concentrations of $Ca^{+2}$, $Na^{+1}$, $Cl^{-1}$ and $NO_3^{-1}$ were also found in the first month's rainfall samples.

Analysis by J. H. Feth, S. M. Rogers, and C. E. Roberson of more than 100 samples of snow, 79 of them from the Sierra Nevada, shows western snow water to be dilute relative to snowmelt reported from other areas in North America and Europe. The average concentration of dissolved solids in Sierra Nevada snow was about 5 ppm. Snow from mountains in Utah was somewhat more highly mineralized, and snow samples taken in Denver, Colo., were appreciably more mineralized, and showed the effect of urban influence.

#### Tritium in precipitation and stream water

In the autumn of 1961, after resumption of nuclear bomb tests by the U.S.S.R., a nationwide sampling program was initiated to follow tritium levels in precipitation and surface water. A sharp increase in tritium rainout was observed in the spring of 1962, with some samples reaching 1,700 T.U. (1 T.U.=1T atom/$10^{18}$ H atoms) in the midwest, and about 300 T.U. on the east and west coasts. A similar rise was observed in the spring of 1959 after the 1958 test series, and analyses of precipitation samples collected during the spring of 1963 indicate a similar increase.

Samples of stream water from major representative river basins in the United States were collected to correlate tritium runoff with tritium rainout. Preliminary results reported by G. L. Stewart and C. M. Hoffman show no appreciable rise in tritium levels in streams until June 1962, about 2 months after the tritium-rainout peak. The tritium level in most of the streams sampled increased from about 60 T.U. to about 300 T.U. in June 1962. An exception to this was observed in the Yukon River in Alaska, where the peak occurred in January 1962 and reached an activity of about 600 T.U. or higher; the exact peak value is not known as no samples were taken from February through April. Definitive conclusions cannot be drawn from these findings, however, because both the frequency of sample collection and the geographic distribution of sampling stations were inadequate. The nationwide stream-sampling network has been revised, and investigations are being continued so that more accurate conclusions can be drawn.

#### Deuterium and tritium exchange between raindrops and environment

Laboratory experiments devised by Irving Friedman (1–62) in collaboration with L. Machta and R. Soller of the U.S. Weather Bureau were used to study the exchange of water vapor between a falling rain droplet and its environment. The results confirm theoretical predictions of a relatively rapid exchange of deuterium between droplet and environment when neither net condensation nor evaporation takes place. The need for caution in interpreting deuterium and tritium measurements is emphasized.

A series of atmosphere samples taken between August 1957 and January 1958 were analyzed for tritium and deuterium by Von Gonsoir of Heidelberg University and Irving Friedman.[94] Appreciable variations were found which are only partly accounted for through local admixtures of industrial hydrogen. The analytical data reveal an abnormally high concentration of tritium which probably resulted from the direct injection of unburnt tritium in a nuclear explosion.

## STUDIES OF STREAMS AND LAKES

### Strontium in river waters

Because radioactive strontium is one of the most hazardous of radioactive species, the Survey is studying the natural occurrence of stable strontium in water. M. W. Skougstad and C. A. Horr (1–63) found that the strontium concentration in 75 major rivers of the United States ranges from 0.007 to 13.7 ppm. Of more than 175 ground-water samples analyzed, 60 percent contained less than 0.2 ppm, although some potable supplies contained 50 ppm.

### Lithologic control of mineral content of Sierra Nevada rivers

Studies by G. V. Gordon of the mineral composition of the Kings, Kaweah, and Tule Rivers that drain the western slope of the Sierra Nevada indicate that lithology of the drainage basin determines to a major extent the chemical quality of the stream water. Although water of all three streams would be classified as of the calcium bicarbonate type, the percentage reacting value of magnesium increases conspicuously from the Tule on the south to the Kings on the north. The percentage reacting value of magnesium was 13 percent in the Tule River, 14 percent in the Kaweah River, and 20 percent in the Kings River. A substantial portion of the drainage area of the Kings River is underlain by metamorphosed magnesium-rich ultrabasic intrusive rocks and dolomitic limestones. In contrast, the Kaweah and Tule Rivers drain predominantly granitic terrane. The water of the Kaweah River is only slightly more mineralized than that of the Kings River, but water of the Tule River is about 2½ times as concentrated as that of either of the other two streams.

### Lithologic control of mineral content of southern Appalachian streams

Lithologic control on the chemistry of water was also noted by R. J. Pickering in Poplar Creek, a small stream (drainage area 120 sq mi) in east Tennessee which drains areas in both the Valley and Ridge province and the Cumberland Plateau province. Bicarbonate is by far the most abundant anion in water from tributaries draining the coal-bearing clastic rocks of the Cumberland Escarpment. Although calcium and magnesium are the predominant cations in all the streams in the Poplar Creek basin, tributaries draining the Cumberland Escarpment contain significantly more sodium and have a lower pH than do those draining rocks of the Valley and Ridge province.

[94] Gonsoir, von, Bernhard, and Friedman, Irving, 1962, Tritium und deuterium in atmosphärischen Wasserstoff: Zeitschr. für Naturforschung, v. 17, no. 12, p. 1088–1091.

### Dissolved solids load of Cane Branch, Ky., increased by strip mining

J. J. Musser found that chemical weathering and erosion have accelerated in the Cane Branch basin, McCreary County, Ky., because unweathered rocks have been exposed to the atmosphere in the course of strip mining of coal. Cane Branch had an average dissolved-solids content of 138 ppm from October 1956 to September 1958, following mining in 1956.

Additional mining caused the average dissolved-solids content to increase from 358 to 522 ppm from May to August, 1959. From August 1959, when mining ceased, to September 1960 the average dissolved-solids content of Cane Branch in summer decreased slightly, to 470 to 490 ppm. Musser concludes that the increased rate of weathering and erosion in the Cane Branch area will continue and that many years will elapse before the spoil banks stabilize sufficiently to produce a water similar in character to that of nearby streams not affected by mining.

### Geochemistry of Deep Spring Lake, Calif.

In a study of inflow to Deep Spring Lake, Inyo County, Calif., Blair F. Jones found that the composition of inflow falls into two major groups based on the gross lithology of initial drainage areas, and is modified before the lake is reached. The chief modifications are alkali solution and alkaline-earth carbonate precipitation, organic reduction of sulfate, alkalinity enrichment by organic decay, and concentration by evaporation. Surface waters at Deep Spring Lake tend to remain separated from intercrustal brines by density gradients for extended periods.

### Salinity of the Salton Sea

Burdge Irelan's studies of the chemical character of the Salton Sea, Calif., indicates that between June 1907 and March 1962 the salinity increased about 9 times, from 3,648 ppm to 33,800 ppm. The increase in chloride concentration was similar (about 8.5 times), but the sulfate concentration increased about 15 times.

## STUDIES OF GROUND WATER

### Hydrochemical facies of the Coastal Plain of North and South Carolina

In continuing the mapping of the hydrochemical facies of ground water of the Atlantic Coastal Plain, William Back and D. H. Lobmeyer have found in North and South Carolina that the percentage of sodium increases downdip within the Tertiary and Cretaceous formations, and that the highest bicarbonate content is in the area of highest chloride content. This is interpreted to be the result of greater solubility of limestone in salt water and the exchange of the calcium ion with the sodium ion of an ion-exchange material.

### Hydrochemical facies of Permian aquifers in Valencia County, N. Mex.

In geochemical studies of water in the San Andres and Glorieta Formations (Upper Permian) of the southern border of the San Juan basin, Harry E. Koester has delineated basin-type sulfate and chloride facies, high-shelf bicarbonate facies, evaporite sulfate facies, and possibly a nitrate facies. Marked vertical differences in cation facies were noted in the San Andres–Glorieta sequence. Sodium facies prevail in the uppermost part of the sequence. Ion exchange is an important factor within the karst-erosion surface, where Triassic (Chinle) shale is intermingled with the Permian limestone. Calcium-magnesium facies prevail in the dolomite-rich middle part of the San Andres Limestone. Calcium facies in the basal part of the Glorieta Sandstone are attributed to gypsum in the lower part of the Glorieta and in underlying gypsiferous Yeso Formation. High chloride content is generally associated with faults.

### Hydrochemical facies aid in subsurface mapping in Georgia

C. W. Sever found that mapping hydrochemical facies aided in delineating a negative structure involving the principal artesian (limestone) aquifer in southwestern Georgia. Data from 117 wells penetrating the principal aquifer show that ground water in the negative structure has greater sulfate content, higher total hardness, and a higher ratio of magnesium to calcium than ground water on either side of the structure. The boundaries of the structure, as determined from the chemical character of water, agree with the boundaries as determined by surface and subsurface geologic mapping.

### Abnormal content of orthophosphate in ground water of Puget trough

A. S. Van Denburgh and J. F. Santos report that ground water in a broad area of western Washington contains above-normal concentrations of orthophosphate. Throughout much of the State, orthophosphate concentrations are commonly less than 0.10 ppm, but ground water in the Puget trough apparently extending south into the Willamette Valley of western Oregon commonly contains more than 0.50 ppm of orthophosphate. The maximum observed concentration in this area was 4.2 ppm. The ground water is derived, for the most part, from aquifers in glacial and related deposits of Pleistocene age, and Recent alluvial deposits. Because moderate to high concentrations of orthophosphate are widespread and the orthophosphate concentrations tend to increase with depth and geologic age of the water-bearing deposits, a natural source is suspected, rather than pollution.

### Minor elements related to sources of water in California

A study of the occurrence of 17 minor elements in water of California by William D. Silvey indicates that sea water, surface water, ground water, spring water, and oilfield brine contain different groups of minor elements and are characterized by great differences in minor-element content. For example, samples of some spring water and most oilfield brines contained substantial amounts of germanium, yet germanium was not found in sea water, surface water, or ground water. Vanadium was markedly deficient in waters that contained appreciable germanium, although it was relatively abundant in most ground water.

### Fluoride in ground water of Willcox basin, Arizona

In a study of fluoride in ground water in the Willcox basin, Arizona, L. R. Kister found that a fluoride content greater than 2 to 3 ppm was associated with the sediments and volcanic flows of middle Tertiary age, or with the Precambrian Pinal Schist. The Pinal Schist evidently yields large amounts of fluoride to ground water by weathering of fluoride minerals from joints and fissures. Ground water in contact with the Pinal contains as much as 25 ppm fluoride. Ground water from playa mud commonly contains larger amounts of fluoride. A shallow borehole in the Willcox playa yielded water containing more than 100,000 ppm dissolved solids and 282 ppm fluoride, believed to be the highest fluoride content reported in the literature. Evaporation of shallow ground water beneath the playa evidently caused the concentration of dissolved minerals in the water remaining in the playa mud.

## CHEMICAL EQUILIBRIUM STUDIES

### Calcium carbonate saturation studies

The primary purpose of calcium carbonate saturation studies by the Survey is twofold: to identify and measure the variables that affect the solution and precipitation of any mineral, and to determine what controls the variables, such as flow pattern and mineralogy.

Ivan Barnes in a study of the geochemistry of Birch Creek, Calif., a calcite-depositing stream in an arid climate, concluded that the stream loses $CO_2$ to the air more rapidly than calcite precipitates, leading to an adjustment of the $CO_2$ content of the stream, which becomes more supersaturated with calcite.

Water in thermal springs of the Sierra Nevada characteristically has a pH of 8.5 or greater. Thermodynamic calculations by C. E. Roberson (1–63) indicate that water from two such springs, and from Pyramid Lake, Nev. (pH 8.9), is nearly saturated with calcite. Water from most nonthermal springs in the region is not saturated with calcite.

In a study of the calcium carbonate saturation in ground water in central Florida, William Back (1–63) has tentatively concluded that although the unsaturated water is in an area of general recharge, some has been in contact with limestone for many years and has traveled many miles without becoming saturated with calcium carbonate. This suggests that caverns and fissures can be enlarged hundreds of feet below the water table if the water is undersaturated. The presence of cavities in the areas of supersaturation may indicate that the water was unsaturated at some previous time when the flow pattern was different.

Using samples of ground water from central Florida, New Jersey, Puerto Rico, and Deep Springs, Calif., which are saturated with respect to calcite, Ivan Barnes and Willian Back calculated an ion-activity product for dolomite of 2 or $3 \times 10^{-17}$ which is in good agreement with the equilibrium constant of $1.5 \times 10^{-17}$ determined in the laboratory by James B. Kramer.

Analyses used to calculate the departure of water from equilibrium with calcium carbonate minerals requires careful determination of pH and bicarbonate concentration. The Survey made two widely separated studies (Art. 115) comparing field and laboratory measurements of alkalinity (as bicarbonate) and pH of water samples collected in the Sierra Nevada of California by C. E. Roberson and J. H. Feth and in the Atlantic Coastal Plain of New Jersey by Paul R. Seaber and Peter Anderson. For 88 samples of ground and surface water the average change in pH between field and laboratory was about 0.5 pH unit, and the direction of change was unpredictable. Variations in determined alkalinity, between field and laboratory, likewise show marked spread and no consistency in direction. The New Jersey samples indicated that the field pH was greater than the laboratory pH, except in one sample. The maximum difference between field and laboratory determinations was 2.5 pH units. In all samples, field determination of alkalinity was greater than the laboratory determination. The maximum difference between field and laboratory alkalinities was 33 ppm, but most of the differences were in the range from 5 to 15 ppm.

### Temperature stability of burkeite

Experimental work by Blair F. Jones (1–62) on the double salt, burkeite ($2Na_2SO_4NA_2CO_3$), has established its lower temperature stability limits within normal range of p $CO_2$ in nature as affected by total pressures up to 20,000 atm, and the addition of NaCl. Small variation in unit cell parameters related to composition and temperature have been detected by detailed X-ray analysis. Smaller unit cell volumes are definitely associated with carbonate as opposed to sulfate environments.

### Clay mineral-water reactions

When kaolinite is equilibrated in water at pH 3.5 under standard thermodynamic conditions, W. L. Polzer found that a precipitate of aluminium hydroxide was formed having a solubility equal to that of gibbsite. He also observed that the solubility of laboratory glassware (Pyrex) at this pH was comparable to that of kaolinite, which precluded the use of glass containers in his experiments.

E. A. Jenne and associates have determined equilibrium constants ranging from 0.2 for the reaction

$$\text{K-montmorillonite} + Sr^{+2} = \text{Sr-montmorillonite} + K^{+}$$

to 9.0 for the reaction

$$\text{Na-kaolinite} + Sr^{+2} + \text{Sr-kaolinite} + Na^{+} \cdot$$

These equilibrium constants were valid even in systems that contained more than one type of clay, and should help predict the distribution of radiostrontium between solid and liquid.

### Oxidation-potential studies

In a recently completed study, William Back and Ivan Barnes have shown a relationship between the oxidation potential measured in ground water and the flow path of the water in southern Maryland. The oxidation potential is higher in the recharge areas than it is in discharge areas. The oxidation potential is one of the variables that controls the occurrence and concentration of iron in water; accordingly, a relationship was found between the oxidation state and concentration of iron and the ground-water flow pattern. This statement probably is a valid generalization for any hydrologic system that contains iron-bearing sediments and oxidizable material. The Eh values measured in the field are between those obtained from the solubility of $Fe\ (OH)_{3(c)}$ and those obtained from the solubility of hematite.

The chemical equilibria that control solubility and determine the dissolved species of manganese predominating in natural water were summarized graphically in a study by J. D. Hem (2–63). Oxidation and precipitation of divalent dissolved manganese take place slowly in aerated water at a pH of 8.0, but in the presence of feldspathic sand, the oxidation rate is increased (J. D. Hem, Art. 116).

Jack Rawson (Art. 117) found that manganese was brought into solution from manganese dioxide by dilute solutions of tannic acid, probably through chemical reduction of the manganese to the divalent state and formation of a complex.

## ISOTOPE AND NUCLEAR STUDIES

Isotope and nuclear investigations find many applications in geology by providing quantitative measurements that frequently indicate new modes of attacking old problems. Age measurements cover the span of geologic time from Recent to oldest Precambrian. Uranium and thorium disequilibrium investigations are being rapidly expanded and show promise of developing new concepts of the geochemistry of uranium and thorium and of their decay products. These elements may prove to be useful as tracers of the geochemical behavior of some of the more common elements. Light stable isotopes of oxygen, carbon, and hydrogen afford new insight into processes active now and in past time, not only in the atmosphere and hydrosphere, but also in the lithosphere. Oxygen isotopes are potentially useful in determining temperatures of geologic processes, including ore deposition, and studies of the relative concentration of deuterium are now being directed to efforts of determining the probable sources of ore-bearing fluids. Lead and strontium isotopes find new uses in investigations of crustal evolution, magmas, and metamorphic and sedimentary processes. Solid-state studies contribute to a better understanding of mineralogy and to special problems such as the origin of tektites.

### *GEOCHRONOLOGY*

Investigations of the techniques used in isotopic dating have been continued in a study of the relative abundance ratio of $Rb^{85}/Rb^{87}$ and in the use of amphibole in K-Ar dating. The various methods have been applied to a variety of geologic problems ranging from the use of $C^{14}$ in an attempt to verify old newspaper reports of eruptions of Mount Rainier, to dating by U-Pb isotopic methods of zircon at 3,300 million years, the oldest mineral age reported from the North American continent.

#### Carbon-14 age determinations

The chronology of six distinctive pyroclastic layers in Mount Rainier National Park was established by D. R. Crandell, D. R. Mullineaux, R. D. Miller, and Meyer Rubin (1–62) using carbon-14 ages.

Carbon-14 age determinations were used by C. A. Hopson, A. C. Waters, V. R. Bender, and Meyer Rubin (1–62) to determine the age of the pumice and ash sheet representing the most recent eruption of Mount Rainier as about 550–600 years ago. No evidence was found to corroborate newspaper reports of eruptions from Mount Rainier between 1820 and 1894.

Alluvial deposits in the Thompson Creek watershed, Harrison County, Iowa, deposited in the interval between about 14,000 and 2,000 years ago were studied by R. B. Daniels, Meyer Rubin, and G. H. Simonson (1–63). De Forest is proposed as a formational name for the silty alluvium, approximately 35 feet thick, which is divided into four members. Since about 2,020 years ago, there have been three cycles of erosion and deposition.

Carbon-14 ages were used by H. C. W. Skinner, B. J. Skinner, and Meyer Rubin to determine the age and rate of accumulation of dolomite-bearing carbonate sediments in South Australia. Carbonate from one of the ephemeral lakes in the southeastern part of South Australia was deposited in the interval between 6,000 and 3,000 years ago. The rate of accumulation is estimated to be between 0.2 and 0.5 mm per year.

#### K–Ar, Rb–Sr, and Pb–U age determinations

Zircon concentrates from granitic gneisses at Morton and Montevideo in the Minnesota River valley, Minnesota, analyzed by E. J. Catanzaro (1–63), give a minimum age of 3,300 million years. The isotopic U–Pb ages are discordant, and the possible range in age is from 3,300 to 3,500 m.y., depending on the interpretation that is made of the cause of the discordancy. The zircon ages are the oldest mineral ages for the North American continent.

Hornblende from the gneiss at Morton, Minn. was dated at 2,630 m.y. by H. H. Thomas (1–63). This age is in reasonably good agreement with Rb–Sr mica and K-feldspar ages of approximately 2,500 m.y. and dates the time of the Algoman orogeny. The 3,300 m.y. age for zircon from the same rock, however, indicates a pre-Algoman history of 700–900 million years.

Hornblende ages of approximately 1,800 m.y. from rocks in the Leadville area, Colorado, reported by Thomas, are the oldest ages found to date in Colorado by the U.S. Geological Survey laboratory. An age of 1,100 m.y. for hornblende from the Ore Knob mine, North Carolina, is the first indication that the mineralization may be Precambrian (Grenville).

Glauconite from the upper part of the Missoula Group of the Belt Series has been dated at 1,070 m.y. by the K–Ar and Rb–Sr methods. The occurrence, briefly described by R. A. Gulbrandsen, S. S. Goldich, and H. H. Thomas (1–63), is in the Marias Pass quadrangle, Flathead County, Mont. This is the first glauconite of Precambrian age reported in North

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America. A number of glauconite samples dated in the range 1,000–1,260 m.y. have been reported by Soviet geochronologists from the U.S.S.R. and China.

Potassium-argon, rubidium-strontium, and lead-alpha age measurements by H. H. Faul, T. W. Stern, H. H. Thomas, and P. L. D. Elmore (2–63) are the basis for interpreting tectonic history in Maine, New Hampshire, and Vermont. Relicts of the Grenville orogeny (1,000 m.y.) are found in southwestern Vermont, and subsequent major events are observed for Devonian (400–350 m.y.), Permian (270–230 m.y.), and Jurassic (180–130? m.y.) time. The pattern of ages in the Appalachians is similar to that reported from the Ural Mountains.

Potassium-argon and rubidium-strontium ages were used by S. C. Creasey and R. W. Kistler (1–62) to date the sequence of intrusives and of mineralization in the range from 56 to 72 m.y. in six copper districts in southeastern Arizona.

A survey of the relative abundance ratio $Rb^{85}/Rb^{87}$ in natural silicates was made by C. E. Hedge and S. S. Goldich in collaboration with W. R. Shields and E. L. Garner (Shields and others, 1–63) of the National Bureau of Standards. The $Rb^{85}/Rb^{87}$ ratio of a reference sample of rubidium sulfate was determined as 2.5995 $\pm$0.0015 (95 percent confidence interval). No variations larger than can be accounted for by experimental error were found in 26 minerals and 1 whole-rock sample of aplite. The minerals include biotite, K-feldspar, muscovite, and lepidolite from granite, pegmatite, gneiss, and schist. The isotopic ages of the samples range from 20 to 2,600 m.y The results, indicating no large natural variations, do not support the suggestion that the $Rb^{85}/Rb^{87}$ ratio should be determined for each mineral used in an age determination. The value of 2.599 for $Rb^{85}/Rb^{87}$ was obtained on a mass spectrometer with a 12-inch radius of curvature and a triple-filament mode of ionization. Laboratories using the Nier-type mass spectrometer with a 6-inch radius of curvature and single-filament mode of ionization should determine the value of $Rb^{85}/Rb^{87}$ for their instrument or use Nier's value of 2.591 for the relative abundance ratio, $Rb^{85}/Rb^{87}$.

Algebraic and graphic procedures for calculating $Pb^{206}/U^{238}$, $Pb^{207}/U^{235}$, and $Pb^{207}/Pb^{206}$ concordant and discordant ages are discussed by L. R. Stieff, T. W. Stern, and R. N. Eicher (1–63).

Lead-alpha ages, however, for younger zircons commonly give older ages than K-Ar and Rb-Sr ages for the associated micas. This disagreement may result from the superior resistance to metamorphism of zircon compared to that of micas. A problem of this type is being investigated in rocks collected by B. F. Leonard from the Idaho batholith. The K-Ar ages for biotite range from 65 to 72 m.y., whereas the lead-alpha ages are 110–290 m.y. Zircon from two samples of hypersthene-quartz monzonite porphyry from the Thiel Mountains, Antartica (Ford, A. B., 1–63), give lead-alpha ages of 530, 630, and 620 m.y. The lower age is similar to K-Ar mica age reported from McMurdo Sound.

### Lead-alpha age measurements

Lead-alpha determinations by T. W. Stern on zircons from the Minnesota valley gave ages in the range from 2,600 to 3,000 m.y. and led to the isotopic U-Pb rating. The lead-alpha age determinations are in the range of the $Pb^{206}/U^{238}$ determinations made by E. J. Catanzaro. Good correlations between lead-alpha and $Pb^{206}/U^{238}$ ages generally are found; however, the lead-alpha method fails to indicate the discordancy of the isotopic ages, and hence for old zircons that contain only small amounts of common lead, the lead-alpha ages tend to be minimum values.

### Protactinium-thorium dating

Attempts to determine the age of Pleistocene carbonate rocks by measurements of the $Th^{230}/U$ and $Pa^{231}/U$ ratios were continued by J. N. Rosholt in collaboration with P. S. Antal of the Marine Laboratory of the University of Miami. A study (3–63) of marine limestones, calcareous tufa, and cave stalagmites shows that the method probably will not be practicable because significant amounts of uranium are lost by leaching.

### Natural radioactive disequilibrium studies

The isotopic fractionation of uranium in sandstone deposits in the Western States is being studied by J. N. Rosholt in collaboration with W. R. Shields and E. L. Garner of the National Bureau of Standards (2–63). Preliminary results show deviations in $U^{235}/U^{234}$ ratio throughout a range from 40 percent excess $U^{234}$ to 40 percent deficient $U^{234}$ with respect to the $U^{235}/U^{234}$ ratio in the National Bureau of Standards natural uranium reference sample. The deficient $U^{234}$ is leached preferentially to $U^{238}$ and the excess $U^{234}$ is believed to result from deposition of $U^{234}$ enriched in solutions from leached portions of the deposits.

## LIGHT STABLE ISOTOPES

### Oxygen and carbon

The fractionation of $0^{18}/0^{16}$ between coexisting calcite and dolomite from lead-zinc deposits of the Mississippi Valley type was determined by Irving Friedman and W. E. Hall (1–63). Determination of $\delta\, 0^{18}$ and $\delta\, C^{13}$ of coexisting calcite and dolomite showed little fractionation in mineral pairs and raises a question concerning earlier data for Leadville, Colo., where Engel, Clayton, and Epstein [95] found large fractionation between calcite and white coarsely crystalline dolomite, but not between calcite and fine-grained dolomite. The Leadville deposit represents a high-temperature environment, whereas low-temperature conditions prevailed in the Mississippi Valley deposits.

### Deuterium in fluid inclusions

The relative concentrations of deuterium in water of fluid inclusions were determined by W. E. Hall and I. Friedman [96] to supplement chemical analyses of the primary fluid inclusions in ore and gangue minerals from the Cave-in-Rocks district, Illinois, and the Upper Mississippi Valley zinc-lead district of Wisconsin, Illinois, and Iowa. Compositional changes are related to the paragenetic sequence of the ore and gangue minerals, and the concentrations of deuterium are used as a guide to the possible sources of the mineralizing fluids.

The fluid inclusions in early ore minerals are concentrated sodium and calcium chloride brines and are similar to some analyzed samples of connate water. Quartz and sulfides, intermediate in the sequence, contain fluid inclusions with a composition indicating a change that may have resulted from the introduction of magmatic water. A lower relative deuterium concentration was found in these minerals. Gangue minerals of the last stages of mineralization have fluid inclusions with chemical and isotopic characteristics suggesting meteoric water or mixed waters of meteoric and possible magmatic origin.

## *LEAD ISOTOPES*

The isotopic composition of lead in volcanic glasses from the Western States less than 50 million years in age is being investigated by B. R. Doe in cooperation with George R. Tilton of the Geophysical Laboratory, Carnegie Institution of Washington. Lead, uranium, and thorium concentrations are also being determined. The isotopic composition of the glasses differs widely, and isochron model ages range from 1,200 m.y. to −600 m.y. (future age), in marked disagreement with the known ages of recent to 50 m.y. The lead of the volcanic glasses could not have been entirely derived from a uniform infinite reservoir as required by the isochron models. The glasses may represent magmas derived from upper crustal materials, a variable mantle, or contaminated magmas.

[95] Engel, A. E. J., Clayton, R. N., and Epstein, Samuel, 1958, Variations in isotopic composition of oxygen and carbon in Leadville limestone (Mississippian, Colorado) and its hydrothermal and metamorphic phases: Jour. Geology, v. 66, p. 374–393.

[96] Hall, W. E., and Friedman, I., 1963, Chemical and isotopic composition of fluid inclusions, Cave-in-Rock fluorite district, Illinois, and Upper Mississippi Valley zinc-lead district, Wisconsin–Illinois–Iowa: Econ. Geology. [In press]

Lead isotope data from a number of mining districts in the northern Rocky Mountains are summarized by R. S. Cannon, Jr., A. P. Pierce, J. C. Antweiler, and K. L. Buck (1–62) The isotopic composition of the ore lead shows a relation to the age of the host rocks, from extremely primitive lead that gives model ages greater than 2,000 m.y. in the old Precambrian metasedimentary rocks at Atlantic City, Wyo., to J-type lead with future model ages in upper Paleozoic rocks in the Wood River district, Idaho. In the Coeur d'Alene district, major deposits give model ages of 1,400 to 1,200 m.y., whereas minor deposits generally yield younger model ages in the ranges 1,400 to 100 m.y. The isotopic analyses do not clearly prove or disprove the apparent Precambrian age of Coeur d'Alene ore lead.

An unusual zoned galena crystal from the Tri-State mining district is described by R. S. Cannon, Jr., K. L. Buck, and A. P. Pierce (1–63). The sample is from the Netta mine in the Picher-Miami area, Ottawa County, Okla. Preliminary isotopic analyses show a systematic increase in the $Pb^{206}/Pb^{207}$ and in total radiogenic lead from inner to outer growth zones. The lead deposited from ore-bearing solutions was progressively enriched in radiogenic isotopes as the crystal grew.

The concentrations of common lead in some Atlantic and Mediterranean waters and in snow were investigated by M. Tatsumoto in collaboration with C. C. Patterson of the California Institute of Technology. Snow samples from three falls in Lassen Volcanic National Park were found to differ in isotopic composition from lead in pelagic sediments. The difference is attributed to contamination by lead aerosols from tetraethyl lead.

Lead concentrations in Atlantic and Mediterranean waters are less than 0.1 $\mu g$ per liter. In samples from the Mediterranean the lead concentrations are high in surface waters and uniformly low in deeper water, similar to the distribution in Pacific Ocean samples off southern California. Atlantic Ocean samples have no uniform trend with depth. It appears possible that lead tetraethyl contamination can be used as a tracer in the study of oceanic circulation.

The isotopic composition and concentration of lead in brine from the Niland drill hole in California were determined by B. R. Doe in a cooperative study with D. E. White. The brine contained 104 ppm of lead and $0.0053 \pm 0.0008$ ppm of uranium. The isotopic composition resembles closely lead from the west coast obsidians. The brine lead has isotopic ratios of $Pb^{206}/Pb^{204}$ and $Pb^{208}/Pb^{204}$ that are smaller than those for galena ores of the Mississippi Valley type, which are the largest lead deposits in the United States.

## SOLID-STATE STUDIES

### Luminescence and thermoluminescence studies

Using color filters, F. E. Senftle and P. Martinez have determined the spectral distribution of thermoluminescence glow curves for thallium-activated cesium iodide from 4.2°K to 305°K, and for pure CsI from 4.2°K to 290°K. The spectral distribution of the fluorescence emission was also measured on the same specimens from 77°K to 290°K, and that of alpha and gamma scintillation luminescence was measured at 126°K, 164°K, and at room temperature. The normal mode-of-decay scintillation luminescence in "pure" CsI as well as the new (100 n sec) mode reported last year (1–62) are in the 3,000–4,000 Å band. A new mode of decay has been found in CsI in the 4,600–5,000 Å band between 130°K and 160°K having a decay time of 1–2 $\mu$sec. A model proposed to explain the combined thermoluminescence, fluorescence, and scintillation phenomena in cesium iodide will be presented together with the data in a report now in preparation.

### Magnetic properties of tektites

The magnetic susceptibility and percentage of ferrous and ferric iron, manganese, and titanium have been determined for 21 bediasites and 4 philippinites. The magnetic susceptibility of tektites is dependent principally on the ferrous iron, with a small, but significant, contribution for the ferric iron. Neglecting the small contribution of other transition elements, but correcting for the ferric iron, an expression is given for the susceptibility in terms of the total iron. This relationship was verified experimentally, and a method is proposed for the determination of ferrous iron (Thorpe, Senftle, and Cuttitta, 1–63). The coefficient of correlation between ferrous iron determined chemically and magnetically is 0.985. An approximate value for ferric iron can also be calculated. The coefficient of correlation between ferric iron determined chemically and magnetially is 0.740.

Use of the method on tektites from other strewn fields (areas) shows that it is generally applicable to all tektites. When used on synthetic glasses of tektitic composition, the method was shown to be nonapplicable, and the data tend to support the concept that tektites have been subjected to reducing conditions.

### Magnetic properties of ice

The magnetic susceptibility of ice has been measured by F. E. Senftle and A. N. Thorpe[97] from 77°K to 245°K. Ice has a temperature-independent diamagnetism of $-0.683 \pm 0.001 \times 10^{-6}$ emu per g. Further measurements down to 4.2°K show a decrease in diamagnetism below 20°K. The reason for this change is not known and additional measurements are planned to clarify the problem. A review paper by Senftle and Thorpe (1–63) describes the techniques of measuring the magnetic susceptibility of ice, and some of the effects of the adsorption of oxygen on the magnetic properties. A chapter reviewing the magnetic susceptibility measurements of biological materials has been prepared.[98]

### Influence of the Earth's magnetic field on geomicrobiological processes

A theoretical study has been made of the possible effect of the Earth's magnetic field on the movement and distribution of charged microorganisms in the ocean (Sisler and Senftle, 1–62). Based on a proposed model, a laboratory experiment was designed to show the effect in sea water circulated through a special cell mounted in the field of a permanent magnet. The experimental data support the hypothesis that the vertical motion of bacteria in the sea is influenced by ocean currents in the horizontal component of the Earth's magnetic field.

### Magneto-acoustic studies

Magneto-acoustic studies have been made on fairly pure single crystals of potassium by A. F. Hoyte in collaboration with D. Shelley and E. Mielczarck[99] of Catholic University, Washington, D.C. Ultrasonic longitudinal waves were propagated along the 110 direction. A magnetic field was applied perpendicular to this propagation direction along several crystal axes, and an oscillatory dependence in the attenuation was found with variation in the magnetic field.

Three to four maxima were observed in the region between 500 and 2,000 gauss. The Fermi momentum of potassium was calculated from these measurements and was found to have a minimum value of $72 \times 10^{-18}$ gm-cm/per sec and a maximum value of $81 \times 10^{-18}$ gm-cm/per sec, indicating that the Fermi surface of potassium is slightly ellipsoidal and that the free electronic theory of metals is reasonably good in this case, the error being about 10 percent.

X-ray studies of the crystal have yet to be made to determine the magnetic field directions in order to complete the mapping of the Fermi surface of potassium.

## ISOTOPE STUDIES OF CRUSTAL EVOLUTION

### Strontium

Studies of the relative abundance ratios of the isotopes of strontium by C. E. Hedge and F. G. Walthall (1–63),

[97] Senftle, F. E., and Thorpe, A. N., 1962, Oxygen adsorption and the magnetic susceptibility of ice at low temperatures: Nature, v. 194, no. 4829, p. 673–674.

[98] Senftle, F. E., 1963, Magnetic susceptibility of biological materials *in* Barnothy, M., ed., Progress in biomagnetism: New York, Plenum Press. [In press]

[99] Mielczarck, E., Shelley, D., and Hoyte, A., 1963, Fermi surface of potassium: Phys. Rev. Letters. [In press]

using improved mass spectrometric techniques, permit more precise estimates of some limitations on the composition of the crust and of the mantle. The evolution of the strontium isotopes is traced through measurements of the ratio $Sr^{87}/Sr^{86}$. Simultaneous measurements of the ratio $Sr^{86}/Sr^{88}$ permit a correction for fractionation or mass spectrometer discrimination by normalizing the $Sr^{86}/Sr^{88}$ measurement to 0.1194 and by making a corresponding correction for $Sr^{87}/Sr^{86}$ measurements. The technique and precision of the measurements are given in a paper by Hedge and Walthall.[100]

The initial $Sr^{87}/Sr^{86}$ of the earth is assumed to be that determined for meteorites (0.698). A change in the mantle for this ratio is predicated on measurements of 0.700 for ancient basaltic rocks (2,700 m.y.) and of 0.703 for modern oceanic basalts. These figures indicate a Rb/Sr ratio of 0.02 for the mantle.

Continental volcanic rocks range from 0.703 to 0.711 in $Sr^{87}/Sr^{86}$ at the time of crystallization, and only a vague correlation was found between original ratio and rock type. The original ratio decreases with increasing age of the rock. The average initial ratio of $Sr^{87}/Sr^{86}$ of continental rocks has changed 1.1 percent in the past 3,000 million years, whereas the corresponding change in source region of oceanic basalts has been no more than 0.5 percent.

The variations in initial $Sr^{87}/Sr^{86}$ found so far for silicic rocks are appreciably greater than for mafic rocks. If granitic and intermediate plutonic igneous rocks are formed by magmatic differentiation, considerable variability in the source of basaltic material (that is, the mantle) is suggested. The large terranes of granitic gneisses are also being investigated.

#### Lead

Studies by B. R. Doe (2–62) suggest regional trends in the isotopic composition of lead in granitic rocks. Lead from young obsidians and granites from the west coast of the United States has a narrow range of isotopic composition, from 1.208 to 1.225 for the ratio $Pb^{206}/Pb^{207}$, and appears to have been generated in a source in which $U^{238}/Pb^{204}$ was greater than 9. Lead in young obsidians and granites from the eastern Rocky Mountains, however, ranges from 1.074 to 1.119 for $Pb^{206}/Pb^{207}$, and most appears to have been derived from sources with $U^{238}/Pb^{204}$ less than 9. Lead in obsidians from Yellowstone National Park shows extreme ranges, and appears to have been derived from a source with $U^{238}/Pb^{204}$ of about 6. Values of $Pb^{208}/Pb^{204}$ are more uniform in the two regions and range from 38.5 to 39.5 for rocks from the west coast and from 38.0 to 39.3 for the eastern Rocky Mountains. Thus the obsidians and younger granites of the west coast have a mode of origin that does not involve marked differentiation between uranium and thorium in the source, in sharp contrast with the eastern Rocky Mountains. Older granitic rocks show similar features (Doe and Hart, 1–63). Because the measured value for $U^{238}/Pb^{204}$ in all granitic rocks that have been analyzed is greater than 9, it is unlikely that the obsidians and young granites of the eastern Rocky Mountains represent melted old granites. Either a large component of lead in the obsidian and young granites comes from the upper sialic crust, or the mantle under the continent must have variable values of U/Pb as well as variable Rb/Sr.

[100] Hedge, C. E., and Walthall, F. G., 1963, Radiogenic strontium as an index of geologic processes: Science, v. 140, no. 3572, p. 1214–1217.

## HYDRAULIC AND HYDROLOGIC STUDIES

### *SURFACE WATER*

During the past year, theoretical studies have led to new approaches to the analysis of vertical-velocity profiles, flow and salinity distribution in tidal streams, dispersion of miscible material in open-channel flow, flood probabilities, and reservoir storage. Experimental work has yielded valuable results in such varied fields as dispersion of tracers, shear in open-channel flow, heat dissipation in rivers, and electric analogs of floods. Extensive field studies have been made of measurement of flow by use of tracers, relations of rainfall and runoff, and improvements of methods of estimating stream flow.

#### Statistical analysis of vertical velocity profiles

A statistical model of vertical velocity profiles in a channel of finite depth and infinite width has been developed by N. C. Matalas. A set of particles are assumed to move randomly in a downstream direction, bounded by an absorbing channel bottom and a reflecting water-surface barrier. The mean velocity at a downstream vertical is assumed to be proportional to the expected number of particles passing through the vertical at given depths. If the probability distribution describing the movement of each particle is symmetrical, then the limiting form of the velocity profile is defined by a cosine function. The velocity is a maximum at the surface and decreases according to the cosine law to zero at the channel bottom. This limiting form of the velocity profile is independent of the initial vertical velocity profile. Expressions have been derived for the central moments of the probability distribution for the number of particles at given depths.

#### Longitudinal dispersion of miscible material

The differential equation for longitudinal dispersion of miscible material in steady uniform open-channel flow was solved numerically by N. Yotsukura and M. B. Fiering. The solution shows that the mass center of the dispersed material travels with the mean velocity, and that the change in the standard deviation of the concentration distribution becomes linear with time at a distance downstream from the injection point that is about 80 times the depth. The dispersion coefficient is equal to about 15 times the depth times the mean shear velocity.

Yotsukura (1–63) also applied the one-dimensional energy equation to the analysis of sediment-laden flow through a circular orifice.

### Long-term flood frequencies

W. J. Conover and M. A. Benson (1–63) considered the problem of the assigning of probabilities (or recurrence intervals) to extraordinary flood events. They envisioned an eventual solution to this problem as having three parts: the conversion of flood-peak data at all locations to a comparable basis; the reduction of the data to an equivalent number of independent series; and the assigning of probabilities to the combined individual events. Their study treats the third part of the problem and offers a solution for assigning long-term probabilities to the highest floods known to have occurred at each of several locations, whether or not continuous records have been maintained at the sites.

### Storage-outflow characteristics of nonlinear reservoirs

John Shen (2–63) developed a generalized method for determining the storage-outflow relation of nonlinear reservoirs from recession hydrographs. The method furnishes a simple means of analyzing the flow characteristics of small drainage basins.

### Laboratory results of dispersion of tracers

Study of dispersion in a flume by G. F. Smoot and D. I. Cahal showed that the rate of dispersion of the tracer solution, injected as a plane source into the flow, did not agree with that predicted by existing theory based on a two-dimensional model. The rate of dispersion was found to depend on the rate of energy dissipation, the scale of turbulence, and the roughness of the channel.

### Effect of sudden release of water on dispersion

P. H. Carrigan made a laboratory investigation of the effect of a sudden release of water from a hydroelectric plant on the dispersion of miscible materials. Using a distorted model of the lower Clinch River, he found that the dispersion process due to a sudden release of water is not greatly different from that for steady flow.

### Distribution of shear in rectangular channels

In studies of the distribution of boundary shear as measured with a Preston tube at a cross section 118 feet downstream from the entrance of a smooth rectangular flume, J. Davidian and D. I. Cahal (Art. 113) found that the ratio of the shear on the sidewalls to the shear on the channel bed increased with increasing velocity when the depth of flow was constant. This at least partly explains the tendency of a sand channel stream to widen its channel as the discharge and velocity increase.

### Kinetic-energy coefficient for natural channels

Evaluation of the kinetic-energy coefficient for natural stream channels by Harry Hulsing and Winchell Smith from 154 sets of velocity observations indicated that the average coefficient was 1.36 with a standard deviation of 0.20. The coefficients are much higher than would be predicted from a theoretical analysis of two-dimensional flow, indicating that the shear stress due to the variation of velocity in the horizontal plane is an important source of energy loss in natural stream channels.

### Heat dissipation from a thermally loaded stream

A 48-hour series of measurements by Harry Messinger on the West Branch of the Susquehanna River, downstream from a steam-electric generating plant near Shawville, Pa., indicates that currently used energy-budget methods are inadequate for predicting the temperature die-away pattern of a heated stream (Art. 104). The drop in temperature per unit length of reach was about 50 percent greater than that predicted by theory. The study indicates that evaporation from a stream cannot be accurately determined by mass-transfer equations derived for lakes and reservoirs, because of differences in the relation of surface temperature to body temperature; and that solar and atmospheric irradiation of a river surface in a shaded valley cannot be determined by a radiation measurement taken in a nearby open area. Heat conducted from the water to the riverbed, while measurable, was insignificant compared with other heat-transfer mechanisms.

### Electric analog models of surface flow

John Shen (1–62) utilized electric-analog models in his study of the rainfall-runoff process during flood periods. Rainfall events were simulated by voltage peaks of random height and normal distribution. Drainage basins were simulated by a transit time and a lag time due to the effect of storage. He found that the distribution of flood peaks tends to be normal if the relation between flow and storage is linear, but the distribution of peaks is highly skewed if the flow-storage relation is nonlinear. Shen (1–63) also developed an electric-analog solution for two-dimensional turbulent diffusion.

### Estimating snowmelt runoff from mountain drainages

A rational method of estimating snowmelt runoff from mountainous river basins was successfully tested by S. E. Rantz (Art. 108) in the 245-square-mile watershed of the North Yuba River in the Sierra Nevada in California. The snowmelt formulas are based on physical laws of heat exchange and incorporate constants that reflect the effect of environmental influences such as forest cover and basin exposure. Snowmelt components resulting from radiation, convection, condensation, rain, and ground heat were computed separately. These components were then combined and routed to the stream-gaging station by unit-hydrograph techniques, to reproduce the daily discharge hydrographs for snowmelt seasons in each of 3 years. The general method is applicable in other basins.

### Use of tracers in measuring flow velocity

A need for reasonably accurate information on the time of travel in connection with design of pollution-control measures has stimulated interest in measurements of time of travel with tracers. Many field measurements have been made with Rhodamine B, a commercial dye, and a fluorometer capable of detecting the dye in concentrations as small as one tenth part per billion.

M. R. Collings tested the effects of water temperature, pH, sunlight, and extraneous dissolved or suspended material on the accuracy of fluorescence measurements using the Turner model III fluorometer. Calibration curves for temperature variations were determined for Rhodamine B and Pontacy pink dyes. The effect of pH on the fluorescence was found to be insignificant for waters with pH of 4 or higher. Sunlight had no significant effect on samples analyzed within a few hours of withdrawal. Excellent repeatability of concentration measurements was found for both Rhodamine B and Pontacy pink.

B. Dunn and others successfully measured time of travel on Irondequoit, Thomas, and Allen Creeks near Rochester, N.Y., with Rhodamine B and a fluorometer.

T. J. Buchanan, J. R. Kreider, and others tested the use of Rhodamine B and the Turner model III fluorometer for time-of-travel measurements in streams with flows ranging from 10 to 17,000 cfs and with reaches from 1 mile to about 100 miles long. Concentrations of Rhodamine B as low as half a part per billion were detected reliably.

P. M. Frye used green fluorescein dye injected at a constant rate for 1 day at the point where the stream draining Grassy Cove in the Cumberland Plateau, Tenn., enters Mill Cave, to verify a long-standing theory that water from Grassy Cove emerges 7 miles southeast at Sequatchie Spring at the head of the Sequatchie River. Dye injected into a flow of 3.89 cfs at Mill Cave on September 27 was first detected in a flow of 4.85 cfs at Sequatchie Spring on October 2.

### Rainfall-runoff relations in small watersheds in Texas

Studies were made in two drainage basins in Texas to determine the number of rain gages needed for accurate evaluation of average basin-storm rainfall. C. R. Gilbert and others (1–63) reported that in a 39-square-mile basin in northeast Texas, for two-thirds of the 152 storms studied, average rainfall computed from 4 rain gages was within 8 percent of that determined from 14 rain gages. Similar results with 17 rain gages were obtained by W. B. Mills for the 44-square-mile Deep Creek watershed in the Colorado River basin of central Texas.[101]

Consumption, by evaporation, seepage, and transpiration, of runoff stored at floodwater-retarding structures has been found to exceed the annual runoff in some years, according to a series of studies conducted in Texas.

Consumption of total annual yield can be expected when annual runoff approaches 1.5 inches in the Honey Creek basin (Gilbert and others, 1–63), 1.0 inch in the Elm Fork Trinity River basin (Gilbert and others, 2–63), and 0.8 inch in the Deep Creek basin. A 10-percent consumption can be expected when annual runoff approaches 17 inches in the Honey Creek basin and 10 inches in Elm Fork Trinity and Deep Creek basins. The average consumption for the period of study was found to be 22 percent in Honey Creek basin, 13 percent in Elm Fork Trinity basin, and 27 percent in Deep Creek basin. Evaporation represented 70 percent of consumption in Honey Creek basin and 49 percent of consumption in Elm Fork Trinity basin. Evapotranspiration accounted for 71 percent of consumption in Deep Creek basin.

### Rainfall runoff in mountain watersheds in southern California

J. R. Crippen found from an analysis of data for 16 mountain basins of southern California that natural water loss varies with precipitation and with such basin characteristics as climatic environment, altitude, and geology. In the 16 study basins the mean annual water loss ranged from 27 inches where mean annual precipitation was 39 inches, to 13 inches where mean annual precipitation was 14 inches.

### Runoff from an artificial catchment in Hawaii

In a study of runoff from an artificial impervious catchment in Kona, Hawaii, from 1959 to 1961, S. S.

[101] Mills, W. B., 1963, Hydrologic studies of small watersheds, Deep Creek watershed, Colorado River basin, McCulloch and San Saba Counties, Texas, 1951–61: U.S. Geol. Survey open-file report.

Chinn found that an average of 84 percent of precipitation was captured. Rainfall-runoff relations indicate a rapid decline with time of catchment efficiency of the asphaltic membrane used.

#### Rainfall-runoff relations in western Tennessee

An empirical study of monthly runoff-precipitation relations by calendar months using data from western Tennessee by H. C. Riggs indicates that: (1) for adjacent basins the regression between discharges may be improved only slightly by inclusion of a precipitation parameter, (2) for basins 100 miles apart the best simple regression is between runoff and precipitation and this can be improved slightly by inclusion of an index of antecedent conditions based on discharges from the basin 100 miles away, and (3) the reliability with which monthly mean discharges can be estimated varies considerably with the calendar months.

#### Effects of urbanization on streamflow at Austin, Tex.

According to W. H. Espey, Jr., urbanization of a 4-square-mile drainage area in Austin, Tex., has caused a significant increase in the peak ordinate of the unit hydrograph, a 70-percent reduction in time of rise from base flow to peak discharge, and a 67-percent reduction in lag time.

#### Diurnal effect of evapotranspiration on streamflow in southern New York

A study by F. L. Robison of diurnal fluctuation in streamflow on Cold Spring Brook at China, N.Y., in the Delaware River basin, indicates that evapotranspiration can cause a decrease of about 85 percent of the early morning flow. Evapotranspiration effects become noticeable between 0900 and 1000 hours e.s.t. and reach maximum value by 1700 hours e.s.t.

#### Flow of Logan River, Utah, increased by earthquake

Runoff of the Logan River, Utah, increased from 161 cfs just prior to an earthquake on August 30, 1962, to 183 cfs on September 2, 1962, according to W. N. Jibson, although there was no precipitation on the watershed during this period. Also, the discharge of Dewitt Spring (Logan City municipal supply) increased from 23 to 26 cfs. Comparison with previous years of fall runoff in the Logan River indicates that the increased flow continued at least through September 1962. The increased flow of Dewitt Spring also continued through September.

#### Effect of pondage on peak discharge, Olympic Peninsula

A study has been made of the reduction in peak discharges on a 0.8-square-mile drainage basin on the Olympic Peninsula, Wash., caused by pondage upstream from an embankment with a 6-foot culvert. B. N. Aldridge reports that the maximum reduction in peak discharge was 2 percent, associated with a rate of rise of less than 2 feet per hour. For streams with a more rapid rate of rise, peak discharges would be significantly reduced by pondage.

#### Manning coefficients determined for Cascade Mountain streams

B. N. Aldridge has determined the Manning coefficients for three boulder-bed streams draining from the Cascade Mountains of Washington. The coefficients ranged from 0.055 to 0.25 with many results in the range 0.07 to 0.14. Preliminary analyses show some correlation between coefficients and channel slope, energy gradient, and Froude number.

#### Field tests confirm theoretical culvert computations

Tests made by C. T. Jenkins (Art. 109) on a battery of five 58-inch by 36-inch pipe arch culverts show good agreement between measured discharges and discharges computed by U.S. Geological Survey procedures for calculation of flow through culverts.

#### New record low level in Great Salt Lake, Utah

According to L. N. Jorgensen, the altitude of Great Salt Lake was 4,191.95 feet on December 31, 1962, a new year-end record low for the 112 years of record, and only 0.35 foot above the lowest level measured, 4,191.6 feet in October 1961. These low winter levels and continuing drought conditions indicate that a new record minimum level probably will be reached in the fall of 1963.

The highest altitude reached since regular measurements began in 1851 was 4,211.6 feet in 1873—20 feet above the low of October 1961. Droughts caused low levels of 4,195.8 feet in 1905 and 4,193.7 feet in 1940.

An automatic recorder installed in 1938 has permitted more detailed study of lake levels than was possible earlier from staff-gage readings. Owing to lack of precipitation and deficient streamflow, the lake rose only 0.05 foot in the 3½ months from October 15, 1962 (the seasonal low) to February 1, 1963. The lowest recorded increase in level during the same period was 0.2 foot, the highest was 1.0 foot, and the average was about 0.6 foot.

#### Predicted equilibrium of level of Salton Sea, Calif.

A study of the hydrologic regimen of the Salton Sea, Calif., by A. G. Hely (1–63) and G. H. Hughes shows that the average annual evaporation during 1961 and 1962 based on the water budget was 70.6 inches, and on the basis of the energy budget it was 73.3 inches. Using the average of these two determinations (72 inches) and the 15-year average evaporation from three sunken screened pans, the mean annual evaporation from the Sea for 1948–62 was computed to be 69 inches.

Using this average rate of evaporation, it was determined that a state of quasi-equilibrium will be reached at an elevation of 229 feet below mean sea level, about 3.5 feet higher than the elevation at the end of 1962, if inflow continues at the 1953–62 average rate.

## GROUND WATER

Investigations of principles and processes in the field of underground water made important progress during 1963. Theoretical studies have made new contributions in the understanding of ground-water–surface-water relations (see p. A161), and in the development of analog modeling techniques. Experimental work, chiefly in the area of electric-analog models and hydraulic sand models, has assisted in the solution of complex hydrologic problems not susceptible to mathematical analysis. Extensive field studies of the physical characteristics of aquifers, temperature of ground water, and new approaches to exploration for ground-water supplies are reported.

### Turbulent flow in granular materials

In analyzing the problem of turbulent flow in ground water, W. O. Smith and A. N. Sayre used pipes of circular section 0.01 to 6 inches in diameter to approximate flow channels in rocks. They found that ground-water flow is turbulent in the larger channels (pipes) at relatively slight hydraulic gradients. Under natural hydraulic gradients, turbulent flow probably does not occur in sediments finer than medium to coarse gravel.

### Statistical analysis of aquifer-test data

C. T. Jenkins (Art. 111) demonstrated the application of a graphical method of multiple-regression analysis to a set of hypothetical aquifer-test data to estimate the permeabilities of various layers in the aquifer. The graphical analysis agreed closely with an algebraic analysis of the same data.

### Principles of electric analog models of ground-water systems

H. E. Skibitzke (2–63) described the underlying theory and application of computing systems for determining the hydraulic-potential distribution in ground water as a function of space and time. The systems are of the passive-element direct-simulation type. They make use of the relation between Darcy's law and the Maxwell equations and employ the analogies between electrical resistors and permeability times a distance, and between electrical capacitors and storage coefficient times a volume. Nonlinear computing elements are used to simulate the effects of recoverable evapotranspiration losses and the effects of time-dependent storage characteristics.

### Design of electric analogs for unconfined aquifers

Electric-analog design criteria for flow to wells in unconfined aquifers have been established by R. W. Stallman (2–63). Analog relations derived from the basic differential equations of ground-water motion were applied to construct a finite-difference grid which was used for computing the permeability and specific yield from published pumping-test data. Results of the model study indicate that estimates of permeability and specific yield are highly dependent on the flow conditions which are assumed to exist in the aquifer; and that vertical-flow components near the well, generally not considered in the mathematical analysis of pumping-test data, may be much more significant in the control of water-table decline than radial-flow components for as much as 1 day of pumping. Detailed analysis also indicates that the specific yield during the first few minutes of pumping appears to be a small fraction of that observed after pumping for more than one day.

### Effect of injection on spread of tracers

In a mathematical analysis of the injection of a tracer into a granular medium, Akio Ogata (Art. 55) showed that before a realistic appraisal can be made of the magnitude of spread of a contaminant due to diffusion, consideration must be given to the hydrodynamic condition governing the flow system near the source of injection. To approximate an injection well under field conditions, a point source of injection in an infinite aquifer was assumed. For a large injection velocity relative to the velocity of flow in the ground-water system, the zone of spreading is extremely large compared with the spreading that would occur without a mechanism which tends to disperse the injection fluid.

### Use of radioisotopes to evaluate directional permeability

J. M. Cahill has used a radioactive isotope injected into saturated blocks of porous material to determine the magnitude and direction of permeability. After a quantity of the radioactive material is injected, the block is allowed to dry and then is sawed into sections. Radioactivity assays are then made by exposing beta-ray-sensitive photographic film to the face of each section.

### Electric-analog analysis of periodic flow

Recently developed frequency-selective pressure-measuring devices have made possible the determination of aquifer transmissibility from an analysis of steady periodic-flow conditions. B. J. Bermes, utilizing principles of electric-power transmission and assumed values of transmissibility and storage coefficient, has constructed an electric-analog model which demonstrates that both the Thiem equation and Darcy's law are valid under steady periodic-flow conditions as well as steady continuous-flow conditions. He found empirically that the original assumed transmissibility could be computed from gradient and flow data by using root-mean-square rather than instantaneous values of the hydraulic head.

### Aquifer characteristics in San Joaquin Valley, Calif.

E. J. McCelland and F. S. Riley have reexamined data from a series of aquifer tests in the southern part of the San Joaquin Valley where the thick alluvial aquifer system consists of numerous interbedded coarse and fine-grained strata and is, in general, subject to substantial compaction as artesian head is lowered. This situation is a reasonable approximation of the conditions assumed by Hantush [102] in deriving equations that describe the nonequilibrium-drawdown distribution near a well draining an elastic artesian aquifer, ". . . confined above and/or below by semipervious elastic clay or silt that yields significant amounts of water from storage."

The data were analyzed by conventional curve-matching methods, using a family of "type-curves" of Hantush's function $H(u,\beta)$, plotted on log-log coordinates. Analyses using Hantush functions were applied to tests which, as previously analyzed by the Theis formula, showed progressive increases in transmissibility with distance from the pumped well. Use of the Hantush function produced more consistent and significantly smaller values for transmissibility than those from the Theis formula. The values resulting from use of the Hantush function are believed to be more representative of the true aquifer properties.

### Neutron-probe determinations of storage coefficient

Using a neutron moisture probe to determine the storage coefficient of alluvium of the Arkansas River in Kansas, W. R. Meyer (1–63) was able to get close agreement with storage coefficients determined by pumping tests. Analysis of the pumping-test data by the Thiem equation indicated a storage coefficient of 0.19 gpd per ft., and by the Theis nonequilibrium formula, 0.21 gpd per ft. The storage coefficient determined by the neutron-probe method was 0.205 gpd per ft.

### Permeability of glacial till

S. E. Norris (1–63) concluded on the basis of a study of glacial tills from Ohio and South Dakota that permeability values, although low, are reasonably uniform and can be applied over broad areas in estimating the rate of percolation of water through till to underlying aquifers.

[102] Hantush, M. S., 1960, Modification of the theory of leaky aquifers: Jour. Geophys. Research, v. 65, no. 11, p. 3713–3725.

### Permeability of crystalline rocks of Georgia

J. W. Stewart (1–62) using pressure tests made for underground gas-storage investigations in the Piedmont province in Georgia, showed that considerable movement of ground water is possible through fractures in crystalline rocks at depths as great as 500 feet. He estimates the transmissibility of fractured gneiss at that depth to be about 50 gpd per foot, and suggests that wells drilled to 500 feet should yield 10 to 25 gpm. It was formerly assumed that fractures would be tight and that the crystalline rocks would be virtually impermeable at such great depths.

### High infiltration rates in weathered crystalline rocks

In tests of infiltration rates of weathered crystalline rocks in the Piedmont province of Georgia, J. W. Stewart (2–63) found that the permeability of saprolite was suprisingly high and was comparable to that of granular sediments. Infiltration rates of as much as 1 to 2 inches per hour were reported from some test pits. The highest rates were noted in granite-gneiss saprolite, which is more permeable than saprolite derived from biotite schist or mica-quartz-garnet schist. Where thick, the saprolite yields water freely to wells and in many areas is the principal aquifer tapped.

### New ground-water source in Delaware basin, New Mexico

In connection with Project Gnome in southeastern New Mexico, J. B. Cooper (1–63) delineated a previously little-known ground-water supply. Thick Cenozoic continental deposits as much as 1,400 feet thick fill a deep depression formed by solution of evaporites from rocks of Permian age throughout an area of 150 square miles. Wells tapping these deposits yield large supplies of water of relatively good quality, whereas the older sedimentary rocks yield little water and that is generally saline.

### Permeability of limestones in Tennessee

Preliminary petrographic study of bioclastic limestones from the Highland Rim Plateau in Tennessee, by M. V. Marcher, indicates that those limestones having a high index of clasticity are more susceptible to the development of permeable zones by surface or near-surface weathering than limestones having a low index of clasticity. The abundance of some bioclastic materials, such as bryozoan fragments, is also significant. Weathered coquinites from the Warsaw Limestone are commonly porous and permeable. The type of cement is also an important factor in some bioclastic limestones; partly cemented limestones containing finely broken fossils and other debris are more likely to contain porous and permeable zones than similar limestones tightly cemented with sparry calcite.

### Structural control of ground water in limestones of Bluegrass region

Studies in the Lexington, Ky., area by H. T. Hopkins have indicated that ground water moves rapidly in well-defined channels in cavernous limestone. The direction and areas of movement are controlled by closely spaced joints which occur most commonly along the axes of small synclinal folds.

### Concealed aquifers in glacial-lake deposits

In Kittson and Marshall Counties, northwestern Minnesota, R. W. Maclay (2–62) was able to locate, by careful observation of minor topographic features, highly permeable beach deposits of glacial Lake Agassiz which are concealed beneath younger lacustrine clays. Locally, gentle linear mounds mark the site of the buried beach deposits. Drilling on these mounds and along their extensions has found ground-water supplies in an otherwise nonproductive section.

### Ground-water temperatures indicate directional permeability

E. C. Rhodehamel and S. J. Lang (1–62) in a detailed study of winter ground-water temperatures along the Mullica River, N.J., found that the ground-water movement was dominantly horizontal. This is due to pronounced differences in vertical and horizontal permeability and accounts for layering of ground water noted by other workers in analyzing the movement of contaminants underground.

### Effect of vegetal cover on temperature of shallow ground water

E. J. Pluhowski and I. H. Kantrowitz (Art. 51) found that variations in absorbed solar radiation among differing surface environments in southwestern Long Island, N.Y., results in lower ground-water temperatures under wooded areas than those observed under cleared areas. Shade and a layer of organic material on the ground account for the lesser amount of solar radiation absorbed in the wooded area.

### Differences in ground-water temperature on Long Island

N. J. Lusczynski and W. V. Swarzenski report that ground-water temperatures at Lido Beach, N.Y., increase from 55° to about 66°F between 100 and 1,050 feet below sea level. At corresponding depths, the temperatures are 1° to 2° lower (range increasing with depth) at Lido Beach than at Atlantic Beach, 7 miles to the west in southwestern Nassau County. The temperatures at corresponding depths between 100 and 650 feet below sea level were found also to be about 1° to 2° lower at Atlantic Beach than at Hewlett Neck, about 2 miles landward of Atlantic Beach. These increases in temperatures in a westerly and landward direction are substantiated by ground-water temperatures at public-supply, observation, and other wells in areas south of Sunrise Highway in southwestern Nassau County.

## GROUND-WATER—SURFACE-WATER RELATIONS

For practical purposes ground water and surface water are commonly investigated separately, but in nature such a simple separation is not necessarily realistic. Depending upon the climate, geology, and topography of a given area there may be much interchange between surface waters in lakes and streams and underground water. Many of the Survey's hydrologic investigations are directed toward better explaining this interchange and include studies of the sources and effects of ground-water contributions to streamflow, the effects of changes in stream stage on ground-water levels, and the effects of ground-water pumpage on flow in nearby streams.

### Analysis of ground-water contribution to streamflow

A method of estimating the ground-water contribution to streamflow was developed by M. I. Rorabaugh by using equations and type curves to compute ground-water outflow from a finite aquifer for the following conditions: sudden recharge of the aquifer, sudden change in stream level, constant rate of recharge, and constant rate of change in stream level. The component of aquifer outflow in response to recharge by precipitation and irrigation was computed on the basis of the water level in a well; the component of flow to or from bank storage in response to stage fluctuation of the stream was computed from the stream stage. Combination of the two components produces a synthetic curve of the ground-water portion of streamflow, and provides a basis for forecasting the ground-water portion of the surface-water recession curve.

Rorabaugh has applied these concepts to forecasting low flow of streams in the Bitterroot basin, Montana, where he has shown that ground-water outflow for low-water periods (October–March) has sufficient variation to warrant further evaluation as a forecasting tool. In 5 years of records tested, forecasts of theoretical ground-water outflow have ranged from 15 to 40 percent above the 1936–37 critical low flows and 30 to 60 percent below the observed discharge of the Bitterroot River.

### Effect of ground-water pumping on flow in a nearby stream

E. P. Weeks and D. A. Ericson conducted pumping tests in the Little Plover River basin, Portage County, Wis., to determine the extent of streamflow depletion caused by pumping from nearby wells. The tests indicated that the vertical permeability of the streambed materials controls the rate of streamflow depletion; also, the cone of depression of a well near a partially penetrating stream is larger than the cone of depression computed for the idealized situation of a completely penetrating stream. Unreliable results were obtained by the use of equations based on the assumption that the stream completely penetrated the aquifer.

### Effect of recharge from a stream on ground-water levels

A graphical analysis of the rate of decay of a recharge slug in a wedge-shaped unconfined aquifer bounded by two rivers is described by I. S. Papadopulos (Art. 54) as a means for calculating the ratio between the coefficients of transmissibility and storage. The analysis was based on type curves prepared from the solution of an analogous heat-flow problem in which the boundary conditions were identical.

### Analysis of ground-water changes due to flood waves in streams

Analytic solutions for the changes in ground-water head, ground-water flow, and bank storage caused by flood waves in surface streams were derived by H. H. Cooper, Jr., and M. I. Rorabaugh (Art. 53). For flood-wave hydrographs that may be approximated by a sinusoidal or damped sinusoidal curve, these solutions permit computation of the resulting ground-water movements if the aquifer constants and dimensions are known. For areally infinite aquifers, bank storage declines very slowly after a flood wave has passed.

### Relation of drainage density to streamflow

According to C. W. Carlston,[103] a mathematical model developed by C. E. Jacob,[104] which relates transmissibility to the geometry of a water-table aquifer discharging ground water into streams, was analyzed and adapted to show that base-flow discharge should vary inversely as the square of the drainage density. Flood discharge is shown to vary directly as the square of the drainage density. In a study of 13 small basins in the eastern United States where recharge is practically a constant, the observed relations of base flow and flood runoff to drainage density were found to be in accord with the model's predictions. The mean annual flood runoff from 15 small basins was found to be unaffected by large differences in relief, valley-side slope, stream slope, or amount and intensity of precipitation. Drainage density is adjusted to the most efficient removal of the mean annual flood runoff. The mean annual flood intensity varies inversely with "terrain transmissibility"—a term which describes the capacity of a terrain to accept infiltering precipitation and to transmit it by unsaturated flow through the vadose zone above the water table and by saturated flow through the aquifer to the streams draining the ground water.

[103] Carlston, C. W., 1963, Drainage density and streamflow: U.S. Geol. Survey Prof. Paper 422–C. [In press]

[104] Jacob, C. E., 1943, Correlation of ground-water levels and precipitation on Long Island, N.Y.: Am. Geophys. Union Trans., v. 24, pt. 2, p. 564–573.

### Sources of low flow to streams in the Mississippi Embayment

In studies of low-flow characteristics of streams in the Mississippi embayment, W. J. Perry, J. A. McCabe, and P. R. Speer found that streams in west Tennessee receiving base flow from sands of the Claiborne Group and the McNairy Sand Member of the Ripley Formation have better sustained low flows than streams whose base flow is from other geologic units. The poorest contributors to base flow are the Coon Creek Tongue of the Ripley Formation and the Demopolis Formation. The loess hills in the extreme western edge of the area are also a poor source of base flow.

A distinct change in the low-flow characteristics of the streams was noted near the Kentucky-Tennessee State line. The indices of the headwaters of East Fork Clarks River and of Mayfield and Obion Creeks in Kentucky are among the lowest of any streams in the study area. These streams and the North Fork Obion River in Tennessee drain geologically similar areas, but the streams in Kentucky probably lie above the water tables and therefore are intermittent. Bayou du Chien is the only stream in the area north of Tennessee that shows an index approaching those of other streams receiving their base flow from the Claiborne Group.

### Sources of low flow in the Bruneau River basin, Idaho

H. C. Riggs in studying the sources of low flow in the Bruneau River basin, Idaho, finds that half of the low-flow discharge at Hot Spring gage enters the channel from ground-water sources in the lower 12 miles of channel, and that the largest part enters in the lower 5 miles. One tributary channel about 25 miles long had little change in discharge throughout. Another of similar length and direction of flow showed an increase of 50 percent in the lower half.

### Unfrozen reaches indicate ground-water inflow in Michigan streams

S. W. Wiitala and T. G. Newport (1–63) mapped areas of ground-water inflow to streams in northern Michigan by aerial photography during winter freezes. Areas of open water were interpreted as gaining reaches. Streamflow measurements made the following summer confirmed the interpretations.

### Dissipation of flood flows in arid environment

P. E. Dennis reports that a study of Sycamore Creek basin in Maricopa County, Ariz., has thrown some light on what happens to floodwaters that leave mountains and disappear along "sand rivers" in arid valleys. During one March flood about 5,000 acre-feet of water passed the lower gaging stations in the granite bedrock, at a maximum rate of 300 cfs. After leaving the mountain front the water disappeared in the first 2 miles of the "sand river." Water levels in nearby observation wells rose nearly 70 feet, but in a well 3 miles from the mountain front the rate of decline in water level was merely somewhat reduced for 6 weeks after the flood. Most of the water seems to have been evaporated and transpired close to the mountain front. This information should prove helpful in plans to salvage such water for beneficial use.

## SOIL MOISTURE AND EVAPOTRANSPIRATION

Studies of soil moisture and evapotranspiration have received increasing attention during recent years. This has come about because of the recognition of the significance of soil moisture in the hydrologic cycle, and the need for understanding soil-moisture phenomena to make best use of moisture in the soil. In the arid or semiarid areas occupying much of western conterminous United States, as well as other countries, moisture in the soil represents a very large part of the total moisture received, and locally the water consumed by nonbeneficial plants greatly exceeds the economic uses. Furthermore, knowledge of movement of moisture through the soil is necessary to a fuller understanding of recharge to the ground-water reservoir.

Studies by the U.S. Geological Survey during the year have dealt with the mechanics of soil-moisture movement, the development of techniques for obtaining more accurate measurements, and the relations of soil moisture to use of water by plants and to plant growth. Emphasis has been given to quantitative work.

### Movement of soil moisture through changes in temperature and atmospheric pressure

Field observations made near Elk City, Okla., by R. W. Stallman, R. S. McCullough, and E. E. Parshall have shown that temperature gradients contribute significantly to the movement of moisture in the unsaturated zone. Movement of moisture by thermal energy may account for the water transport in fine-grained materials now unexplained by the concepts embodied in Darcy's law. Wetting of thick clay and silt deposits above the water table during the winter, and drying during the summer, might be explained by thermal drive of water.

Preliminary studies indicate that breathing of the unsaturated zone in response to atmospheric-pressure fluctuations can cause a significant conversion of infiltrated water to vapor loss. Where the unsaturated zone is thick and permeable, several feet of water per year can be pumped from the unsaturated zone in this way. Efficiency of recharging of aquifers in arid zones will be affected markedly by such loss. Furthermore, estimates that have been made of the water consumed by plants where the water table was at depth may have been too high.

### Theoretical analysis of moisture movement across soil boundaries

Situations in which moisture flux across a soil boundary is a known function of surface-moisture content or of time were investigated theoretically by Jacob Rubin, using the transient-state, one-dimensional moisture-flow equation of unsaturated soils. Numerical-difference methods evolved make it possible to use the above equation to predict the change in amount of soil-moisture during a rain of increasing intensity. It was found also that similar predictions could be made in laboratory tests wherein water is absorbed by a soil from an adjacent water-saturated porous plate having a recognizable resistance to water flow and having a surface that is maintained at constant subatmospheric pressure. In addition, semianalytical mathematical methods were developed which make it possible to estimate, for a given soil and a given constant-intensity rain, the amount of water which can enter the soil before ponding occurs. A preliminary test of the latter method showed that the theoretical computations are in reasonable agreement with the experiment data available.

### Changes in cation content of soil moisture

R. F. Miller and K. W. Ratzlaff obtained sufficient corroborating evidence to develop several hypotheses concerning the feasibility of tracing unsaturated moisture movement with soluble cations. The processes of cation exchange and salt precipitation cause soluble sodium concentrations to increase in the direction of moisture movement. Recurring patterns of unsaturated-moisture movement that occur while soil moisture is being dissipated appear to leave a chemical imprint on the soil. Capillary movement of moisture when stresses are greater than 1 bar results in progressive decrease in soluble-cation concentrations in the direction of moisture movements. Soluble-salt concentrations increase at the forward extremities of capillary movement, where moisture moves in extremely thin films through a drying environment.

### Effects of desert vegetation on moisture stress

In a study of energy relations under and adjacent to riparian vegetation in Arizona, R. F. Miller and I. S. McQueen found that during the spring dry period, total moisture-stress gradients are greater in the open spaces between mesquite and cottonwood trees than under the trees. The relation is reversed under and between saltcedar, and the reversal is interpreted as being due to increased osmotic stress resulting from salts exuded from the leaves of saltcedar. It was found also that the moisture that accumulates above abrupt changes in texture interferes with the formation of continuous moisture-stress gradients that could transport water directly from the water table to the soil surface. The capillary fringe is lower under trees than adjacent to them, probably because trees make use of water from the capillary fringe.

### Deep depletion of soil moisture by grasses

Investigations by R. C. Culler, R. M. Myrick, and M. R. Collings of soil moisture on the Fort Apache Indian Reservation, Ariz., have shown that in a grassland, soil-moisture can be depleted to depths of 6.5 feet through evapotranspiration during a summer, including the loss by "breathing" mentioned by Stallman and others (p. A163). The tendency to deplete soil moisture from lower levels seems to be a characteristic of shallow-rooted vegetation as well as of tree-type vegetation.

### Change in moisture content of zone of aeration during water-table declines

Measurements by A. O. Waananen with a neutron soil-moisture meter before and after removal of water from evapotranspirometer tanks indicate that the principal changes in water content occur in the part of the zone of aeration above the saturated portion of the capillary fringe. Dewatering takes place as the capillary fringe declines with the drop in water level. This suggests that study of yields to streams from flood-plain deposits should cover characteristics of the materials above the capillary fringe, as well as those in the zone of water-table fluctuation.

### Evapotranspirometer experiments

Measurements of water use by various types of vegetation and under different climatic conditions were continued during 1963. Evapotranspirometers, which are large soil-filled tanks, were used by three groups of investigators.

Near Yuma, Ariz., C. C. MacDonald and G. H. Hughes (2–63) experienced considerable difficulty in establishing in tanks vegetation typical of the lower Colorado River flood plain. Excessive salinity was found to be a major cause, requiring a program of leaching that will be continued between growing seasons. Data for the last 8 months of 1962 are provisional but indicate that cattail (*Typha latifolia*) uses more water (about 12 inches per month) than is evaporated from a Weather Bureau class A pan (about 10.6 inches per month). In contrast, 0.6 inches per month was lost by evaporation from bare soil with the water table at a depth of 3 feet, and 5 inches evaporated per month from a tank in which water was ponded above the soil surface.

T. E. A. van Hylckama (1–62) using tanks in which saltcedar (*Tamarix pentrandra*) had grown for 3 years near Buckeye, Ariz., found a variation of water use with depth to artificially maintained water tables. With water at a depth of 4 feet, 60 inches are used annually; at 5 feet, the use was 48 inches, and at 9 feet, about 42 inches annually.

T. W. Robinson, in comparing evapotranspiration by willows with losses from bare ground in the Humboldt River valley, Nevada, found that during 1962, willows lost 4.1 feet of water (including 1.36 inches precipitation), whereas bare soil lost 0.5 feet, also including precipitation. On three separate occasions, water use dropped in late summer when potential evapotranspiration is higher than in early summer. Robinson found that on at least one occasion the drop was due to cumulative boron poisoning, which developed in a tank over three growing seasons.

A 50-percent drop in water use by saltcedar in tanks in late summer coinciding with a remarkable decrease in growth rate was reported by T. E. van Hylckama. He is investigating the possibility that this drop is partly due to a lack of carbon dioxide available to saltcedar fronds because of the great density of the vegetation.

Rapid depletion of moisture in the root zone may be another reason for the drop in water use. A. O. Waananen considers this the case in soil-moisture observations made with a neutron-scattering meter near Menlo Park, Calif. Evapotranspiration by natural vegetation decreased from 0.02 feet per day in March to one-tenth of this in late summer.

## SEDIMENTATION

Sedimentation involves the many complex and varied aspects of the erosion, transportation, and deposition of sediments. Current research can be classed in four principal groups: (1) the effects of cultural changes on sediment yield, (2) accumulation of sediment in reservoirs, (3) studies of sediment transport, and (4) deposition and erosion. In addition, the U.S. Geological Survey this year published an annotated bibliography on hydrology and sedimentation compiled by H. C. Riggs (1–62) for the years 1955–58. The suspended-sediment concentration and grain-size distribution of samples collected in the Survey's sediment sampling program are reported in the Water-Supply Paper series "Quality of Surface Waters of the United States." F. H. Rainwater (1–62) compiled a summary of sediment concentration in the rivers of the United States, which formed part of a series of three maps of composition of stream waters.

## EFFECT OF CULTURAL CHANGES ON SEDIMENT YIELD

Cultural changes, such as road construction and land leveling to accommodate urban growth; strip mining; and grazing can greatly alter the sediment regime of a river basin. Depending on the type of activity, the sediment yield may increase or decrease. Most changes result in increases in load, which commonly leads to problems downstream such as reduction in channel capacity due to siltation, shoaling of navigable channels, and excessive costs in processing water for municipal and industrial supplies.

### Urbanization

In the Washington, D.C., suburban area, H. P. Guy reports that from July 1957 to April 1962, when 89 new houses were built on 20½ acres near Kensington, Md., 4,000 tons of sediment was eroded from the building area. This is an average of 45 tons of sediment per building site, or 195 tons per acre. Measurements of sediment discharge in the Potomac River and its tributaries by J. W. Wark and F. J. Keller indicate that heavily forested areas have annual sediment yields of as little as 20 tons per square mile, whereas subbasins in the Washington, D.C., area undergoing urbanization have yields as high as 2,300 tons per square mile. Similar conclusions with regard to the effects of urbanization were drawn by F. J. Keller (1–62) and D. H. Carpenter on the basis of measurements of suspended-sediment concentrations in the Northwest Branch Anacostia River, Md., and by J. R. George (1–63) from suspended-sediment measurements made in the Stony Brook basin at Princeton, N.J.

### Strip mining

Weathering and erosion of spoil banks formed in strip mining of coal have greatly increased the suspended-sediment discharge of Cane Branch in McCreary County, Ky., according to C. R. Collier and J. J. Musser. Mining ending in June 1956 disturbed 6 percent of the Cane Branch drainage basin, and sediment concentrations in Cane Branch averaged 4,800 ppm from June 1956 to June 1959. Renewed mining in 1959 disturbed an additional 4 percent of the drainage basin and caused the mean sediment concentration of Cane Branch to increase to 20,000 ppm during July, August, and September. After mining ceased the mean sediment concentration decreased to 4,700 ppm from October 1959 to September 1960 or to about the same level as before the 1959 mining. Suspended sediment loads in Cane Branch are far in excess of those in nearby Helton Branch, which has not been affected by mining.

### Soil-conservation measures

In contrast with the higher rates of erosion caused by urbanization and strip mining, B. L. Jones found that the suspended-sediment discharge from Corey Creek in northern Pennsylvania decreased about 30 percent between 1954 and 1960 as a result of the conservation measures applied to this 12.2-square-mile drainage basin.

### Grazing

In the arid and semiarid Western States, grazing has greatly altered the sediment regime in many basins. In a study of the effects of grazing exclusion in the Badger Wash basin, western Colorado, G. C. Lusby found that, although the density and character of vegetation in small fenced drainage basins have not changed significantly, both runoff and sediment yield are reduced in the fenced basins. In grazed or unfenced drainage basins, during the early spring when soils are loosened by frost action, trampling by livestock causes compaction of the soil, which results in higher runoff and sediment yields from the grazed drainage basins.

Lusby also reports that annual runoff from the steeper highly dissected areas of shaly soils at Badger Wash is about the same as that from the gentler, less dissected areas of sandy soil. This difference is caused by loosening of the soil by frost heaving, which is most pronounced in the shaly soils. Sediment yields, however, are greater from the shaly areas.

## SEDIMENT ACCUMULATION IN RESERVOIRS

Reduction in storage capacity by siltation is a serious problem in all water-storage reservoirs, and is especially serious in dry climates where sediment loads are high.

In an investigation of channel and flood-plain aggradation along Polacca Wash in northeastern Arizona, R. F. Hadley found that 8 percent of the sediment deposited behind conservation dams is located above spillway elevation, and aggradation occurs at elevations up to 13 feet above the spillways of these structures. Present channel gradients on the sediment deposits range from 0.0005 feet per foot to 0.0037 feet per foot, whereas the gradient of these channels prior to dam construction ranged from 0.0040 feet per foot to 0.0058 feet per foot.

S. A. Schumm has used data collected during reservoir sediment surveys to compare modern rates of denudation with modern rates of mountain building. In general, uplift occurs at a rate about 8 times greater than denudation. Consideration of this disparity between orogeny and denudation suggests that time-independent landforms will not develop and that isostatic adjustment to denudation will occur episodically.

H. V. Peterson (1–62) has published a compilation of sediment accumulation rates in 200 small reservoirs in the Missouri River, Colorado River, and Rio Grande drainage basins.

## SEDIMENT TRANSPORT

### Dispersion of bed material and suspended sediment

D. W. Hubbell and W. W. Sayre have used radioactive tracers to study the dispersion of bed material instantaneously released from a line source extending across a channel. The distribution of particles downstream from the source at various times can be predicted accurately with a mixed-probability distribution function. The sediment distributions are initially highly skewed in an upstream direction but approach a normal distribution as time increases. In contrast with the dispersion of bed material, the dispersion of a very fine suspended sediment (bentonite) is generally the same as that of the fluid and produces a distribution from an instantaneously released plane source that is skewed in the downstream direction.

### Increase in sediment load precedes breakup of ice dam in Alaska

Larry S. Leveen reports a marked increase in suspended sediment downstream from the ice dam at Lake George, Alaska, about 10 days before the annual breakup of the dam. He suggests that the time of the well-known breakup can be predicted with some accuracy by this observation.

### Effect of suspended sediments on form resistance

C. F. Nordin, Jr. (1–63), has concluded that the form resistance in a reach of the Rio Grande near Bernalillo, N. Mex., is reasonably described by the Einstein bar resistance curve. He has also concluded that high suspended-sediment concentrations due to tributary inflow have no measurable effect on resistance coefficients, although there may be large changes in bed-material characteristics.

### Effect of temperature on suspended load

R. K. Fahnestock has found that the depth of flow in the Rio Grande near El Paso, Tex., may vary as much as 1½ feet for comparable discharge depending on water temperature, which ranges from 50°F. in March to 80°F. in August. Warming reduces the viscosity of the water, which reduces sediment transport, and increases the size of bed dunes. This causes increased resistance to flow and increased stages for comparable discharge.

### Gradation of bed material affects sediment transport

In laboratory experiments, D. B. Simons, E. V. Richardson, W. L. Haushild, and H. P. Guy have determined that the gradation of bed material significantly affects the form of bed roughness, resistance to flow, and sediment transport in sand-bed channels. In addition, two separate methods of determining bed-material discharge have been developed, and a method of estimating average velocity of flow in alluvial channels has been developed by correcting for the separation zones downstream from the bed forms.

### Computing sediment load from flow-duration curves

In continuing studies of techniques for calculating sediment movement in rivers, J. R. George and B. L. Jones have developed a method of computing average annual suspended-sediment load for eastern streams using flow-duration curves and relatively few suspended-sediment discharge measurements. They report that comparison of computed versus measured annual sediment loads produced results favorable for design purposes.

### Clay minerals in streams of the United States

In a survey of the sediments transported by some 30 streams in various parts of the conterminous United States, Vance Kennedy has found that in the Eastern United States the most common clay minerals in streams are kaolinite, illite, and dioctahedral vermiculite, but that west of the Mississippi River, montmorillonite, illite, or mixed-layer montmorillonite-illite predominate. These differences are believed due partly to differences in climate.

### Sediment load of Kansas streams

According to C. D. Albert and J. C. Mundorff, highest sediment yields in Kansas are from areas of low to intermediate runoff in loess and glacial-till terrain rather than from areas of greatest annual runoff. The highest weighted suspended-sediment concentrations of major streams in Kansas are in the Cimarron River in southwestern Kansas and in parts of the Republican River system in northwestern Kansas; both drainage basins have very low runoff and are underlain by silty deposits of Pleistocene or Tertiary age. Although southeastern Kansas streams have mean flows in cubic feet per second per square mile as much as 100 times greater than the western streams, their sediment concentrations generally are much lower. Because the runoff differences are proportionally much greater than the concentration differences, the southeastern streams yield more suspended sediment than the western streams.

### Sediment load before logging in Oregon

Investigations are in progress in the Alsea River watershed in the Coast Range of Oregon to determine sedimentation and hydrologic conditions in forested drainage basins under natural conditions, under different timber-harvesting methods, and during the recovery phase of the watershed after the timber harvest. R. C. Williams in an evaluation of the prelogging phase found that about 95 percent of the rainfall and runoff occurs from October to May and almost 100 percent of the suspended-sediment discharge occurs during that period. In the 1960 water year, 23 percent of the annual suspended-sediment discharge occurred in 1 day, 58 percent during the 10 days of greatest flow, and 78 percent during the 38 days of greatest flow.

## EROSION AND DEPOSITION

### Formation and erosion of armored channel beds, New Mexico

In an investigation of channel erosion in the Rio Puerco, N. Mex., C. F. Nordin, Jr., found that channel aggradation, armoring of the bed with fine clay, and subsequent headcutting appear to follow a recurring natural cycle. Channel armoring occurs by deposition rather than by infiltration, and movement of the headcut in the armored layer is a function of the duration of low and intermediate flows rather than of peak discharge or total volume of flow.

### Origin of clay balls

Studies of clay balls in the Rio Puerco near Bernardo, N. Mex., by L. H. Wagner show two possible modes of formation. In one, large masses of plastic clay soil are delivered to the river by bank caving, and assume a spherical form when rolled. In the other, clay-layer polygons soften and are rounded by rolling. Clay balls increase in size by passing over sand and gravel which adheres to the clay mass.

### Channel stability and debris loads

Preliminary observations by K. R. Fahnestock of valley-train processes on White River, Mt. Rainier, Wash., suggest that the farther a reach is from the debris source the more stable it is. This tendency toward stability occurs in spite of the increase in discharge due to contributions of clear-water tributaries, suggesting a cause-and-effect relation between debris transport and bank instability. Fahnestock also reports that there appears to be a correlation between channel width and stability along the Wynoochee River on the Olympic Peninsula of Washington. Narrow stable channels pass quantities of gravel which appear to cause bar formation and bank erosion in wider reaches both downstream and upstream from the narrow reach.

### Scarcity of granule-size material in sediments

L. K. Lustig (Art. 93) found that the granule size class (1–4 mm) is abundant in clastic sediments in Deep Springs Valley, Calif. About 80 percent of the granules are polymineralic rock fragments. He attributes the scarcity of granules in rivers and in most ancient as well as recent sediments to the rapid breakdown of the granules into their component sand-size grains during transport. A hydraulic explanation for the absence of granules in sediments is therefore unnecessary.

### Competence of transport on alluvial fans

In a companion study in Deep Springs Valley, Calif., Lustig (Art. 92) estimated the competence of transport on alluvial fans by means of a field approximation based on maximum particle size and slope. Plotting of isopleths of these values on a map shows inferred paths of sediment transport.

W. B. Bull (1–63) reported that deposition of alluvial-fan deposits on the west side of the San Joaquin Valley, Calif., is caused mainly by decrease in depth and velocity of flow resulting from increase in width as a flow spreads out on a fan. Loss of water to dry surface materials also is an important control of competence. Decrease in slope is not an important factor because most of the streams show no change in slope where the stream enters the valley.

### Experimental deformation of unconsolidated materials

Laboratory studies on deformation in unconsolidated sediment by E. D. McKee, M. A. Reynolds, and C. H. Baker, Jr. (2–62), showed that stratification in unconsolidated sediment may be contorted in a variety of ways, depending largely on the type of material involved and on the physical process causing deformation. In a series of experiments, sand responded very differently than did mud. Sand that was saturated or immersed in water behaved unlike that which was merely wet or was dry. Deformation from gravity slumping differed from that caused by vertical loading, pushing with lateral force, or dragging by an overriding force.

In other laboratory experiments the same workers (1–62) were able to produce intraformational recumbent folding by pushing with lateral force and by dragging with an overriding force. Other processes failed to develop this structure. Differences in axial trend differed with the position of water level; differences in the shape of folds seemed to be controlled by the rate of deformation. Intraformational recumbent folds have been recognized in sandstones of various ages, notably among strata considered to be of fluviatile origin. Recurrent floods forcing masses of sediment across newly formed foreset beds probably account for most examples.

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### Effect of base-level rise on bedding development

In flume experiments on the effect of a moderately rapidly rising base level on the development of bedding in a ripple or dune environment, A. V. Jopling (Art. 56) found that the system adjusts by aggrading the bed toward a new profile graded to the new base level. The configuration of the bed is continually remolded as successive ripples or dunes override and partly assimilate their predecessors. The bedding developed is irregular, undulose, lenticular, trough-shaped, or festoonlike.

### Contrast in skewness of bed and bank sediments

Preliminary results of a study of the effect of sediment characteristics on fluvial morphology indicate that for alluvial rivers of the Great Plains the grain-size distribution curves of bed and bank sediments are generally skewed in opposite directions. R. W. Lichty reports that bank samples are generally skewed toward the fine-sediment fraction. The absence of a tail of course sediments in the banks is related to the competency of the transporting medium and may indicate the upper size limit of sediment carried in suspension at discharges associated with bankfull stage. The grain-size distribution curves of bed material are generally skewed toward the coarse sediment, probably because the fine sediment is winnowed out of the bed and transported as wash load.

### Sedimentation in Mammoth Cave, Ky.

Observations of changes along Echo River in Mammoth Cave, Ky., by R. F. Flint and C. R. Collier between October 1959 and August 1961 indicate that the higher less-frequent floods tend to deepen the channels of Echo River, whereas the lower more-frequent floods tend to fill these same channels. In higher passages that are above water except during floods, deposition generally occurs regardless of flood magnitude.

### Paleowind directions in longitudinal dunes

Dissection of a Libyan seif dune led E. D. McKee and G. C. Tibbetts [105] to conclude that longitudinal or seif dunes, characteristic of some of the world's great sand deserts, have crossbedding structures that dip at right angles to the dune crest, but not to the wind directions. The crossbed structures thus fall in two groups with dominant dip directions about 180° apart. In sandstones formed from ancient dunes, therefore, it is possible to distinguish seif dunes from other types, and to determine paleowind directions from them.

[105] McKee, E. D., and Tibbetts, G. C., 1963, Primary structures of a seif dune and associated deposits in Libya: Jour. Sed. Petrology. [In press]

## LIMNOLOGY

Limnological investigations by the U.S. Geological Survey comprise studies of the biological and physical controls of the physical and chemical quality of water in lakes and other bodies of ponded water. Present investigations are concerned chiefly with changes in the dissolved-mineral content of water and formation of mineral precipitates through organic activity, thermal and density stratification of water in reservoirs and the effects of thermal changes on organic activity, and laboratory studies of organic systems in water.

### Changes in water quality related to organic activity

Changes in water quality resulting from accumulation of tree leaves in marginal pools during the autumn low-flow period were studied by K. V. Slack in the Cacapon River, W. Va. Water color increased as leaf litter decomposed, and the concentrations of aluminum, nickel, iron, manganese, alkalies, and carbon dioxide were significantly higher in leaf-filled pools than in the clear flowing river water. Dissolved oxygen decreased as water color increased. Abnormally low calcium concentration in one isolated pool may have resulted from ground water discharge into the pool, base exchange with leaf organic matter, or utilization of calcium by snails in shell formation.

### Changes in water quality in subterranean channels

K. V. Slack found significant changes in composition of water of Gandy Creek, W. Va., where it flows for about 3,000 feet through a cave. When sampled in October the temperature of the inflow was 57° F and of the outflow 48.5° F. The outflow contained higher solute concentrations than the inflow; bicarbonate increased from 21 to 38 ppm, specific conductance from 45 to 75 micromhos, calcium from 6.8 to 12 ppm, and total dissolved solids from 30 to 39 ppm. Increased concentrations in the outflow may result from addition of high-bicarbonate ground water, or from solution of limestone due to increases in the carbon dioxide in solution. Increase in carbon dioxide can be accounted for by lower water temperature and by organic decomposition in the cave without concurrent uptake of the gas by photosynthetic plants.

### Depletion of silica by diatoms in Upper Klamath Lake, Oreg.

Studies by R. J. Madison of the quality of water flowing into and out of Upper Klamath Lake, Oreg., indicate that diatoms may at times remove more than 95 percent of the silica from the lake water. The Williamson River contributes about 85 percent of the total inflow to the lake. Silica concentrations in quarterly water samples from the Williamson River ranged from 29 to 37 ppm during the 1962 water year. Similar samples of lake water at its outlet ranged from 32 to 46 ppm except for the June 4, 1962 collection. On that date a diatom bloom was observed in the lake, and the silica concentration of outlet water was reduced to 1.5 ppm. Silica measured 30 ppm in the Williamson River. Concentrations of silica increased downstream from the Klamath Lake outlet as a result of inflow from tributaries and irrigation return.

#### Aquatic plants remove lead from solutions

Experiments by E. T. Oborn (Art. 118) showed that common water-rooted aquatic plants and bacteria remove lead from very dilute solutions. The amount of lead extracted from water is approximately proportional to the plant surface area in contact with the water.

#### Role of natural antibiotics in aseptic organic muds

A paper given at the International Limnological Congress in Madison, Wisconsin (August 1962), documented the accumulation of practically aseptic organic mud high in protein and vitamin-$B_{12}$ content in parts of Lake Victoria in central Africa. This led W. H. Bradley to propose the theory that such aseptic organic muds accumulate only in water shallow enough, or clear enough, to permit certain algae and (or) photosynthetic bacteria to grow on or very close to the surface of the mud. It is known that certain algae and free-living bacteria produce vitamin $B_{12}$ and toxins or antibiotics that protect them, while living, from attack by destructive bacteria and fungi. The theory postulates that the algae and (or) bacteria living on or close to the organic-mud surface provide an aseptic environment that protects the accumulating organic mud from decay. Such a mechanism would account for the beautifully preserved microorganisms found as fossils in certain rich oil shales and also would explain certain oil shales that are known from geologic evidence to have accumulated in shallow water.

#### Fixing of calcium carbonate by bacteria

E. T. Oborn has found that a gram-negative bacterium tentatively identified as *Bacterium precipitatum* Kalin is associated with mineral matter, mostly calcite, deposited on sago pondweed (*Potamogeton pectinatus* L.). The deposit obtained from specimens of this plant growing in a Phoenix, Ariz., irrigation canal was about 12 percent of the total dry weight. The symbiotic association of plants and microorganisms may be an important factor in biochemical removal of dissolved mineral matter from lakes and rivers.

#### Experiments in photosynthetic oxygen production

Preliminary tests with the standard light-and-dark-bottle method for estimating photosynthetic oxygen production showed that temperature differences between the two bottles may result from a greenhouse effect. When clear and blackened BOD (biological oxygen demand) bottles were exposed under the surface of flowing water for 1 hour on a sunny day, K. V. Slack observed 0.5°C increase in temperature of the clear bottle over that of the stream or the blackened bottle. Increased rates of respiration and photosynthesis may result from higher clear-bottle temperature and may lead to erroneous interpretation of data.

#### Solute concentration in Lake Abert, Oreg.

In a study of Lake Abert, a saline closed-basin lake in south-central Oregon, A. S. Van Denburgh found that concentrations of all major solutes except silica and orthophosphate vary inversely with lake volume. Sodium, potassium, carbonate-bicarbonate, sulfate, and chloride maintained constant relative proportions over a range of dissolved solids from about 40,000 ppm to 75,000 ppm during the period April 1961 to December 1962. Anomalous variations in concentrations of silica and orthophosphate are probably controlled by biologic activity. In the case of silica, changes in solubility with changing dissolved-solids content and water temperature also may account for variations in concentration. The most abundant constituents in Lake Abert are sodium, carbonate, and chloride. Estimated maximum values for less abundant solutes are: silica, 210 ppm; fluoride, 10 ppm; bromide, 125 ppm; orthophosphate, 105 ppm; and boron, 105 ppm.

#### Thermal stratification in lakes in northern Alabama

Thermal surveys of Inland Lake, Sylacauga Reservoir, Tuscaloosa County Lake, and Walker County Lake in north-central Alabama reveal a characteristic annual pattern of thermal stratification in deep, relatively static impoundments, according to L. B. Peirce. Thermal stratification begins in March and reaches its maximum development in August and September. By early December, vertical mixing by convection destroys temperature gradients and the reservoirs are nearly isothermal. This condition continues, with further cooling of the entire water body, until spring. Surface temperatures range from 40° to 95°F annually; at depths of 80 feet or greater, a much smaller range was observed, from 44° to 50° F. Lay Lake, a hydroelectric-power reservoir on the Coosa River in the same area, exhibits a similar annual pattern of stratification but with temperature gradients reduced by inflow and turbulent mixing. The annual range of surface temperature in Lay Lake was about the same as in Inland Lake, but at the 50-foot depth in Lay Lake the temperature range was more than three times that of Inland Lake.

#### Stratification in Texas reservoirs

Reservoir studies in the Brazos River basin, Texas, by H. B. Mendieta and J. F. Blakey demonstrated density stratification in Whitney and Possum Kingdom Reservoirs but not in Belton Reservoir. These results are partly explained by the relation between inflow rate and dissolved-solids content of inflowing waters. Belton Reservoir, holding water of excellent quality, shows only minor changes in dissolved-solids concentration from low to high rates of inflow. In this study, dissolved-solids concentration of inflow to Whitney Reservoir varied from 700 to 1,440 ppm and in Possum Kingdom Reservoir the range was 850 to 4,200 ppm. The temperature of inflow water affects stratification and mixing in these reservoirs, but density stratification is caused mainly by salinity variations. In Possum Kingdom Reservoir, for example, one series of chloride determinations showed 520 ppm at the surface and 760 ppm at a depth of 90 feet. Reservoirs of this type may allow high-quality water to pass over spillways during floods, while retaining more saline water near the bottom.

#### Effect of thermal loading on dissolved oxygen

F. E. Clarke and K. V. Slack studied the dissolved oxygen in the West Branch Susquehanna River. They noted that thermal loading through use of the river for cooling at the Shawville, Pa., steam-electric powerplant caused marked changes in the oxygen regime. At the station below the powerplant, the water temperature was an average of 13°C higher owing to the discharge of warm water. The river, which is acid from strip-mine drainage, was supersaturated with dissolved oxygen at all times below the powerplant and during most of the daylight hours above the plant. There was a moderate decrease in oxygen concentration at night above the plant. The oxygen concentration was always lower below the plant, owing to lower solubility of gases in warm water. The high dissolved-oxygen values probably are due to (1) shallow depth, which favors atmospheric reaeration, (2) slow oxygen utilization by decomposable organic matter owing to the acidity of the water, and (3) oxygen production by riverbed plants.

## GEOMORPHOLOGY

Geomorphic studies continue to follow recent trends, with emphasis on quantitative investigations of streams, their channels, and their sediment load; on climatically influenced processes such as frost action and mass movement; and on research relating measurements of processes or combinations of processes to the resultant landforms.

#### Morphology of stream channels

Upstream flood regulation on Sandstone Creek near Cheyenne, Okla., since 1950 has resulted in perennial streamflow from reservoir seepage, and establishment of permanent riparian vegetation. These factors in turn have caused the channel shape to change from a rectangular to a **V** profile, as measured by D. L. Bergman and C. W. Sullivan (Art. 97). Other results are higher stages during floods, entrenchment of the low-flow stage in a narrowed channel, an increase in the size of sediment carried along the bed at low-flow stage, increased scour, and the formation of small riffles.

Sinuosity of stable river channels of the Great Plains is related to the channel shape, and to the percentage of silt and clay sized particles in the channel perimeter. The more sinuous the river, the deeper the channel and the higher the proportion of fine sediment on the channel sides, according to S. A. Schumm (1–63) and R. W. Lichty.

#### Comparison of drainage features on topographic maps

E. V. Giusti and W. J. Schneider (1–63) considered the problem of using standard topographic maps to evaluate stream frequency and other geomorphic variables. On the basis of an analysis of eight different map series in the Piedmont province, they developed a ratio to convert counts of first-order streams in one series to comparable values in any of the other series.

#### Denudation by solution in the Potomac River basin

H. R. Feltz and J. W. Wark (1–62) in studies of the mineral content of precipitation and runoff in the Potomac River basin concluded that denudation by solution ranged from 11 to 354 tons per square mile per year. Maximum rates were in tributary basins where coal is strip mined, and in streams draining limestone and dolomite.

#### Geomorphology related to ground water

Karst features in the Madison Limestone in northwestern Wyoming apparently formed in two or more stages. An ancient period or periods of karst development is evidenced by several zones of caverns and sinkholes, some of which are filled with old sedimentary breccia. A late Pleistocene or Recent episode of karst development is evident in Tosi Creek Basin in the southeastern part of the Gros Ventre Mountains (Art. 34). Here W. R. Keefer found a karst topography that formed after the disappearance of the Pinedale (or late Wisconsin) glacier which filled the basin. He postulates that these solution features formed under a cool climate by melt water and later by runoff which penetrated fractures in the limestone and entered ancient karst passages below.

### Gravity and frost phenomena

Slope orientation plays an important role in the occurrence of freezing and thawing during the winter months, in soil moisture content, and in mass movement, as shown by R. F. Hadley on Green Mountain near Denver. South-facing slopes experience a freeze-thaw cycle almost weekly in the winter, whereas north-facing slopes remain frozen. South-facing slopes have about twice as high a soil-moisture content as north-facing slopes and are sites of active landslides.

The classic "Cerro Till" in Colorado, mapped as pre-Wisconsin drift by Atwood and Mather, has been found by R. G. Dickenson to be a product of mass movement. The movement has been complex, grading from simple creep, through earthflow and mudflow, to gravity sliding of large blocks. No evidence of pre-Wisconsin glaciation was found in the area.

In western Colorado, S. A. Schumm finds that creep rates on sparsely vegetated hillslopes of Mancos Shale are higher than those in humid regions, and that the creep rates are a positive exponential function of slope inclination.

Frost action, under a climate colder than the present, has apparently created a distinctive sorted pattern in the upland soils of the Snake River plain, Idaho, that resembles the patterned ground of Arctic regions where these forms are forming today. The patterns, according to H. E. Malde and H. A. Powers, consist of polygonal networks enclosing mounds 50 to 60 feet in diameter. The network is made up of a vertically sorted stone pavement, and is composed of various materials, including basalt, alluvial-fan gravel, and welded tuff.

The study of the origin, distribution, and age of pingos in interior Alaska, conducted by G. W. Holmes, D. M. Hopkins, and Helen L. Foster (1–63), has shown they belong to the "open system" type; that is, they formed from ground water moving downslope beneath permafrost to a point where the water lifted the overburden and formed a large ice lens and a mound. The presence of springs on their summits that flow even during the coldest winters suggest they may be useful indicators of ground water.

The geologic significance of snow avalanches is little appreciated in the United States, although they are one of the principal means by which high mountains are sculptured. Avalanche scars are well developed in the Middle Fork of the Kings River in the Sierra Nevada, Calif., as shown by G. H. Davis (1–62). Here many of the cliffs have a fluted surface, on which straight smooth gullies alternate with rock ribs. Some gullies are wider at the top than at the bottom, and others are branched. The mechanics of scour involves the movement of snow which carries abrasive rock debris, such as talus. Most of the sculpturing evidently took place in the Pleistocene Epoch.

## PLANT ECOLOGY

Knowledge of the relation of plants to their environment is essential in many fields of geologic and hydrologic investigations. In most of the world, use of water by plants accounts for the consumption of a large part of the precipitation. Moreover, plants exercise great control over erosion and deposition and are of special interest as indicators of concealed rocks, of past climates, and of floods. Their role as consumers of water is described specifically under Evapotranspiration, page A163.

### Relation of plants to lithology and soil moisture

Relation between the lithology of soil parent material and the plants which are characteristic of certain sites are being studied by F. A. Branson, R. S. Aro, and R. F. Miller on a variety of geologic terranes from New Mexico to Montana. Several widely distributed plant species such as big sagebrush (*Artemisia tridentata* Nutt.), silver sagebrush (*Artemisia cana* Pursh.), needle-and-thread (*Stipa comata* Trin. and Rupr.), and western wheatgrass (*Agropyron smithii* Rydb.) indicate different soil-texture conditions which strongly influence plant-water relations. Examples have been found where adjacent but sharply contrasting plant communities, which share the same macroclimate, slope, and exposure, demonstrate the effect of lithology alone on vegetation. Presence or abundance of other plant species such as big sagebrush (*Artemisia tridentata* Gray) seem to reflect the combined factors of availability of soil moisture and geochemistry. Along the eastern limits of its distribution, flat sagebrush is restricted to calcic materials with low soil-moisture stress. In certain areas near La Junta, Colo., this species should be useful for delineation of the Fort Hays Limestone Member of the Niobrara Formation and similar limestone units. In some instances, plants may indicate a single geochemical control. For example, winterfat (*Eurotia lavata* (Pursh.) Moq.), a valuable forage plant, was found to occur only on calcic soils over a large part of its distribution.

Study of pinyon-juniper woodlands and adjacent grasslands in Arizona, New Mexico, and Texas by R. S. Aro indicates that the distribution patterns of these plant communities are controlled by lithology and soil development. Where pinyon-juniper woodlands and grasslands form an association complex, the woodland type usually occupies the rocky sites characterized by exposed parent rock material and immature soils, whereas grassland communities occur on the finer textured, more fully developed intervallic soils. Location, amount, and availability of soil moisture stored in these contrasting sites relative to competing root systems appear to be the main ecologic controls. Present work is aimed at determining what soil conditions are critical for grassland establishment in areas where conversion of pinyon-juniper woodlands may be proposed.

#### Significance of tree form and growth in geomorphic processes

In dendrohydrologic studies in Hocking County, Ohio, conducted in cooperation with G. E. Gilbert of the Ohio State University and the Ohio Agricultural Experiment Station, R. L. Phipps has found evidence suggesting that bent or leaning trees indicate certain microclimatic conditions. Over a large area in southeastern Ohio, most trees growing on slopes in closed forest were found to be leaning downslope from the vertical, and the degree of leaning appears to be a function of slope steepness and direction of slope exposure. The major cause of leaning trees is concluded to be a difference in reception of sunlight between the upslope and downslope sides of the tree crowns.

Other causes of bent trees were physical interference or growth from stump sprouts. No evidence was found to support the widely held theory that leaning or bent trees resulted from soil or slope movement.

Erosion of forested slopes in the White Mountains, near Bishop, Calif., has exposed the roots of millenia-old bristlecone pines (*Pinus aristata*). These roots can be dated by counting and correlating the annual growth rings. Comparison by V. C. LaMarche, Jr., of the depth of exposure with the age of the root gives a measure of the rate of erosion. The rate increases with the slope angle, reaching a maximum of about 1 foot in 1,000 years on the steepest (35°) slopes. Local rates of denudation have been fairly uniform during the past 3,000 years (Art. 98).

In the study of botanical evidence of floods and flood-plain deposition, R. S. Sigafoos found that the banks of part of the Potomac River are defined by the channelward limit of perennial plants. In humid regions, these plants are tree species. Seed germination, establishment of seedlings, and maturation of trees on the banks are dependent upon a complex but orderly sequence of botanical and hydrologic events. Thus, the line of trees represent the maximum high water mark of the river during extended periods of low flow. Evidence in the form of trees on the flood plain of the Potomac suggests that vertical erosion and accretion are important processes modifying the surface. The flood plain consists of alternate erosional and depositional surfaces at any one time, and tree forms indicate a sequence of erosion and deposition at a place through time. This results in the temporary storage of alluvium on flood plains similar to temporary storage of alluvium in point bars.

#### Seasonal growth in relation to hydrologic environment

Plant development, soil moisture, and microclimatic measurements were made in 1962 by F. A. Branson, A. M. Sturrock, R. F. Miller, and R. S. Aro on residual soils on the Ogallala Formation along a thermal gradient from western Nebraska to southeastern New Mexico. Progressive plant development within species in early May shows a positive relationship with decreasing latitude. However, preliminary analyses of the data indicate that change in date of anthesis within species along the transect is considerably less than would be predicted by Hopkins's bioclimatic law. Additional analyses may permit a rational revision of Hopkins's law.

Preliminary data analysis by R. L. Phipps, in connection with the dendrohydrologic studies in Ohio, suggests that the distinction between phenological seasons (seasons based on time of such plant phenomena as leafing out and leaf fall) corresponds to the time of major changes in soil moisture and fluctuations in soil water table of the forested area. Furthermore, the time of radial growth of trees in the area corresponds with these seasons, thus tree-ring growth is more closely related to hydrologic parameters summarized on a phenological-season basis than on a monthly or yearly basis.

#### Tree ages and growth rates on modern glacial moraines

In connection with continuing studies of the modern history of alpine glaciers on Mt. Rainier, Wash., by R. S. Sigafoos and E. L. Hendricks, D. R. Crandall suggested that the trees on lateral moraines are considerably older than trees on terminal moraines formed by the same advance. Sigafoos and Hendricks found additional data confirming this at Emmons and Winthrop Glaciers. The ages of the trees on the lateral moraines indicate the time when the glaciers start to recede, thus the older trees show that the surface of up-valley parts of alpine glaciers lowers many years before the terminus becomes stagnant.

Analysis of periods of suppressed growth (a series of years when trees grow more slowly as indicated by ring widths) in older trees growing near the moraines shows that a high percentage of trees grow more slowly immediately prior to the start of recession of the glaciers. Presently available data show only the higher percentage of suppressed trees prior to the recession that began about 1840. Too few very old trees were sampled to develop this relationship for periods prior to recessions starting about 1745 and 1635.

## GLACIOLOGY

U.S. Geological Survey personnel are studying existing glaciers in order to learn the hydrologic peculiarities of glacier runoff, to understand more about the continuing enigma of glacier flow, and to find out how a glacier adjusts to its climatic environment. Studies of the deposits remaining from past glacier advances are lending insight into climates of the past, and are providing needed information which is important to the fields of ground-water and engineering geology. Results of studies of Pleistocene glacial geology are to be found in discussions of Regional Geology, beginning on page A71.

### South Cascade Glacier, Wash.

Detailed results on net budget, ice flow, and changes in ice thickness from 1958 to 1962 of South Cascade Glacier in Mount Baker National Forest, Wash., have been brought together and analyzed by M. F. Meier and W. V. Tangborn. This appears to have been the first integrated study of a complete glacier in which the changes in the glacier surface profile can be related directly to net budget and flow. This study was designed, in part, to provide numerical data for the development of a theory of the response of glaciers to climatic change. Dr. J. F. Nye in England, who has just developed such a theory, used the South Cascade Glacier results as a test case. In general, the field results confirm theoretical predictions; for instance, the rate of thinning of the glacier as a function of distance agrees very well with predictions based on analysis of kinematic wave velocity and diffusivity. For the first time it has been possible to make quantitative statements about climatic change from direct measurements of changes in the profile of this glacier. As a byproduct of this study, Meier and Tangborn were able to calculate the discharge, thickness, and shearing stress on the bed of South Cascade Glacier.

The net budget of South Cascade Glacier in the budget year 1961–62 was slightly positive; an average increase of 16 cm prevailed over the glacier surface. This is somewhat remarkable because the snow accumulation during the winter was less than usual and the summer rate of melt was normal. The growth in the glacier was due almost entirely to a cool wet spring. These results confirm what glaciologists have long suspected—that temperature and precipitation in spring and fall are of critical importance in determining the net budget of a glacier.

### Kinematic-wave studies on Nisqually Glacier, Wash.

The remarkable kinematic wave of Nisqually Glacier, Wash., which caused 100-foot changes in ice thickness and 20-fold changes in ice velocity, seems to defy present theoretical understanding. Studies by M. F. Meier and J. N. Johnson show that the linearized (perturbation) theory of kinematic waves as developed by Weertman and Nye, and the theory of glacier slip on bed as developed by Weertman, do not apply to the situation on Nisqually Glacier.

### Recent glacier variations

Recent thinning of South Cascade Glacier has uncovered a bedrock area with numerous tree roots and stumps in place. A sample of this wood collected several years ago by M. F. Meier and E. L. Hendricks has recently been found by Meyer Rubin to have a radiocarbon age of 4,700±300 years B. P. Apparently South Cascade Glacier has been larger than its present size since this early date. This result is unusual because it indicates a glacier advance during the period which has been called "altithermal" or "climatic optimum" by many writers, long before the Little Ice Age.

T. L. Péwé has photographed the fronts of glaciers in the McMurdo Sound area, Antarctica, and compared these positions with the position of the fronts 50 years ago. His studies suggest that the glaciers are in dynamic equilibrium, which supports similar evidence from elsewhere on the continent. Other results from Antarctica are given on page A105.

East-west and north-south cross sections of Alaska constructed by T. L. Péwé show the present, Wisconsin, and Illinoian snowline elevations as computed from cirque bases. These indicate that the present and past snowlines are low in the south and west but rise continuously to the east toward Canada and to the north into the Brooks Range. The elevations of active, well-developed solifluction lobes show a similar distribution, but are everywhere lower than the snowline elevations.

## PERMAFROST

Temperature measurements were continued in several areas of Alaska and in northern Canada. The measurements covered the permafrost regime in deep wells as well as in the active zone overlying permafrost.

In cooperation with the Jacobsen–McGill University Arctic Research Expedition, A. H. Lachenbruch and G. W. Greene installed a thermistor cable to a depth of 2,000 feet in the northernmost oil well (dry) in the world, recently drilled on Melville Island, N.W.T., Canada. Preliminary temperature measurements, accurate to about 0.01°C, indicate that subfreezing temperatures extend to a depth of about 1,500 feet—the greatest measured depth of permafrost in North America. At the time of observation, heat from the drilling operation had not yet dissipated, so measurements to be taken periodically in the next few years are expected to show progressively decreasing temperatures and "thickening permafrost".

In the Big Delta area, Alaska, preliminary data indicate a significant variation in the depth of frost penetration due to the time and amount of snowfall relative to the onset of low winter temperatures. Observations in Alaska by D. B. Krinsley (Art. 38), supplementing similar findings in Wisconsin and the U.S.S.R., suggest that increases of 1 to 4 inches in the thickness of a 6-inch snow cover significantly dampen the fluctuation of the ambient air temperature.

Studies of ground-water occurrence in permafrost areas were made in Alaska in cooperation with the U.S. Air Force, and several gallery-type wells have been installed at various places in permafrost areas of Alaska. The past year has proven the advantages of this type of water-supply installation in certain situations where drilled wells are either impractical or yields are too low for normal use. Certain Air Force installations have been provided with year-round water supplies for the first time through use of such gallery supply wells.

At an Air Force installation near Bethel, a water well was drilled in 1962 through 603 feet of permafrost and reached potable water under pressure below permafrost. Temperature determinations made on the subpermafrost water show it to have a temperature of 33.2°F. Circulation of warm (57°) water down the well and into the aquifer prevents freezing of the well. This well has the thickest penetration of permafrost of any producing water well in Alaska.

Quality of water observations made in conjunction with the ground-water studies by A. J. Feulner and R. G. Schupp (Art. 52) show that a gradual but marked increase in mineralization of water from shallow sources in permafrost occurs during the colder months and a rather rapid decline to the level of summer concentration takes place in early spring.

# LABORATORY AND FIELD METHODS

## ANALYTICAL CHEMISTRY

### Sulfate and sulfide sulfur in rocks

A method for determining both sulfate and sulfide sulfur in rocks was devised by Ann Vlisidis. The sample is digested with a 1 percent HCl solution containing $CdCl_2$ and $BaCl_2$. Calcium sulfate, for example, would be transposed and the released sulfate fixed by the barium sulfate. At the same time, the $H_2S$ released from a sulfide decomposable by dilute HCl is fixed as insoluble CdS, effectively preventing the possibility of its oxidation to sulfate. After filtration, the residue is fused with $Na_2CO_3$ and the melt leached with water. The solution is filtered, and barium in the insoluble residue is determined. Sulfate sulfur (that transposed plus that originally present as barite and not transposed) can then be computed. Sulfide sulfur is obtained from the difference between total sulfur (separately determined) and sulfate sulfur.

### Separation of traces of tellurium from iron and gold

Microgram amounts of tellurium can be separated from up to 150 mg of iron and 10 mg of gold by an extraction procedure developed by C. E. Thompson and H. W. Lakin (Art. 44). Iron and gold are extracted as thiocyanate complexes from 0.5*N* hydrochloric acid by a solution of tributylphosphate in ether. Tellurium is not extracted if the thiocyanate concentration is not excessive.

Studies on the occurrence, distribution, and abundance of tellurium have been limited by the lack of sufficiently sensitive analytical methods. Of great importance, therefore, is the development by H. W. Lakin and C. E. Thompson of a new, extremely sensitive method for the quantitative determination of tellurium.[106] It is based on the induced precipitation of elemental gold from a 6*N* solution of hydrochloric acid containing gold chloride, cupric chloride, and hypophosphorous acid; the amount of gold reduced is proportional to the amount of tellurium present. As little as 1 nanogram ($1 \times 10^{-9}$) of tellurium gives a measurable reaction with 1 mg of gold in 50 ml of solution. Use of this method should yield much useful data on the abundance of tellurium in geologic materials.

### Neutron-activation analysis of fluid inclusions

Edwin Roedder, in cooperation with G. K. Czamanske (formerly of Massachusetts Institute of Technology and now at the University of Washington) and F. C. Burns (Watertown Arsenal) have made the first known neutron-activation analyses for heavy metals in fluid inclusions.[107] Manganese, copper, and zinc were determined on fluids extracted from primary fluid inclusions in crystals of fluorite from southern Illinois and in quartz from the OH vein at Creede, Colo. Although the amounts of each of the metals found were in the range of only 1 to 10 $\mu g$, they were far above the limits for the methods used, and indicate that relatively large concentrations of each of these metals (up to 15 percent) were present in solution during trapping. The metals must be in solution, because the inclusions contained no visible solid phases.

### High-purity lead-salt isolates for isotopic analysis

A simple method for preparing high-purity lead-salt isolates for isotopic analysis was developed by J. C. Antweiler (Art. 102). Nitric acid and water, both readily purifiable, are the only reagents required. Lead minerals are first decomposed with hot dilute nitric acid. Lead nitrate is then isolated and purified by repeated precipitation from concentrated nitric acid solution. Only barium and strontium accompany lead. The nitrate is readily converted to the iodide, sulfide, or other compound suitable for isotopic analysis.

### Tantalum in rocks and minerals

Joseph Dinnin completed the development of a method for determining tantalum in rocks and minerals. The practical lower limit of detection is 0.2 $\mu g$ of tantalum, thus allowing the determination of a few tenths of a part per million of tantalum on a 1-gram sample. Niobium and tantalum are isolated together by extraction with methyl isobutyl ketone from HF–HCl solution and returned to an aqueous phase by stripping with dilute $H_2O_2$. Following a modification of a recently described Russian procedure,[108] tantalum is separated from niobium by extracting the tantalum fluoride–methyl violet complex with benzene from 0.05*N* HF, and is determined in the benzene phase spectrophotometrically. Results on U.S. Geological Survey standard granite and diabase, G–1 and W–1, agree with values obtained by Atkins and Smales,[109] who used

[106] Lakin, H. W., and Thompson, C. E., 1963, Tellurium; a new sensitive test: Science, v. 141, no. 3575, p. 42.

[107] Czamanske, G. K., Roedder, Edwin, and Burns, F. C., 1963, Neutron activation analysis of fluid inclusions for copper, manganese, and zinc: Science, v. 140, no. 3565, p. 401–403.

[108] Poluetkov, N. S., Kononenko, L. I., and Lauer, R. S., 1958, Extraction-photometric determination of tantalum, boron, indium, and rhenium: Jour. Anal. Chemistry U.S.S.R., v. 13, p. 449.

[109] Atkins, D. H. F., and Smales, A. A., 1960, The determination of tantalum and tungsten in rocks and meteorites by neutron activation analysis: Anal. Chemica Acta, v. 22, p. 462–478.

neutron-activitation methods. As part of a program on the geochemistry of minor elements, tantalum-niobium ratios were determined on a number of rocks and minerals such as gabbro, biotite, hornblende, magnetite, sphene, and ilmenite.

### Separation of coesite and stishovite

A method based on differential solubility in hydrofluoric acid was developed by J. J. Fahey (2–63) whereby coesite and stishovite, high-pressure polymorphs of silica, are separated and individually recovered from rocks which have been subjected to high pressure by meteoritic impact (see also p. A129). Stishovite is not attacked by concentrated HF at steam-bath temperature and can be separated from coesite, which dissolves readily in this medium. By heating for several hours at 900°C., stishovite is converted to silica glass, in which form it is soluble in 5 percent HF. Coesite is only slowly attacked by 5 percent HF and is obtained as a residue.

### Apparatus for automic potentiometric titration of chloride

An automatic potentiometric titration apparatus for the determination of chloride was assembled by Irving May, F. O. Simon, and R. V. Fones. The electrode system consists of a glass and a silver chloride electrode. The potential is amplified with an expanded-scale pH meter and is recorded on a small recorder. The titrant is delivered with a constant-rate automatic buret. Potential calibration is made with a unit consisting of a compact decade potentiometer with a stable mercury-battery voltage source. Convenient plug-in connectors and switches enable the components to be withdrawn for use in other instruments. Well-defined titration curves are obtained for chloride with 0.005*N* silver nitrate in volumes of 100 ml. The equipment has been used for determining the residual chloride content of Mohole test borings and is used routinely for determining the chloride content of spring waters.

### Synthesis of liebigite

A new procedure for the synthesis of liebigite, $Ca_2UO_2(CO_3)_3 \cdot 10\text{–}11H_2O$, was described by Robert Meyrowitz, D. R. Ross, and A. D. Weeks (Art. 43). The liebigite crystals form as a pure phase from an aqueous solution at pH 8.0–8.2 containing uranyl nitrate, sodium carbonate, and calcium nitrate. Crystals begin to form within a few hours and crystallization is completed in 2 weeks.

In similar procedures with potassium rather than sodium carbonate, large amounts of well-formed, greenish-yellow crystals were obtained alone or together with liebigite. These crystals are believed to be a new uranyl tricarbonate having the formula,

$$K_2Ca_3(UO_2)_2(CO_3)_6 \cdot 9\text{–}10H_2O.$$

### Synthesis of large crystals of swartzite

Large crystals (3×10 mm) of swartzite, $CaMgUO_2(CO_3)_3 \cdot 12H_2O$, a rare secondary uranium mineral, can be prepared, without the necessity for seeding, by a procedure developed by Robert Meyrowitz (1–62). The crystals form in 2 weeks from a solution of $Ca(NO_3)_2 \cdot 4H_2O$ and synthetic bayleyite ($Mg_2UO_2(CO_3)_3$ $18H_2O$) where the Ca:Mg mole ratio is 3:4.

## OPTICAL SPECTROSCOPY

### Quantitative spectrochemical analysis with direct-reading equipment

An Ebert convertible spectrograph has been programmed by A. W. Helz to "read" lines for Ba, Sr, Be, Cr, Pd, V, Cu, Zr, Y, Sc, Ni, and Co simultaneously. Sol Berman is conducting work on these elements. Minor changes in the instrument readily adapt it to use on special problems such as reading lines for B, Pb, Ga, Be, and Li, or for studying Hf and Zr.

### Determination of Hf-Zr ratios in zircons

The direct-reading spectrometer in conjunction with a controlled atmosphere, d-c arc, and small sample size, has been shown by C. L. Waring to be very effective for the determination of hafnium percentages and hafnium-zirconium ratios in zircons. One-milligram samples are burned in a 20-ampere d-c arc for 3 minutes. A controlled atmosphere of 20 percent oxygen and 80 percent argon is used. The Zr 2681.7 A and Hf 2738.7 A lines are recorded directly with photomultiplier tubes, and the electrical output is integrated over the exposure time. Comparative analyses indicated excellent agreement with the results of X-ray fluorescence.

### Cesium, rubidium, and lithium in tektites

C. S. Annell developed a procedure to determine very low concentrations of Cs, Rb, and Li in tektite samples. A mixture of 10 mg of the tektite sample and 20 mg of $K_2CO_3$ is prepared for burning in a d-c arc. The following lines are recorded: Cs 8521.1, Rb 7800.2, Rb 7947.6, and Li 6707.8 A. Standards are made from National Bureau of Standards 183 lepidolite by diluting with a synthetic tektite matrix. The analysis of about 60 tektites indicated cesium concentrations between 1 and 10 ppm, Rb, 40 and 150 ppm, and Li, 30 and 70 ppm. Interesting correlations relative to the tektite strewn fields were suggested by the results.

**Percent-constituent printing accessory for a spectrophotometer**

Spectrophotometric measurements and the subsequent calculations have been automated by a percent-constituent printing accessory for a spectrophotometer designed by L. Shapiro and E. L. Curtis (Art. 103). As solutions of different color densities are poured through a simple flow-through cell in the spectrophotometer, the sensitiviey of the spectrophotometer is automatically readjusted by a servo-driven 10-turn log-wound potentiometer so that percent transmission continuously reads 100. The angular rotation of this potentiometer is directly proportioned to the change in concentration of the colored solutions. A linear potentiometer is geared to the log-wound potentiometer and serves as a read-out device. A digital-voltmeter–printer combination is connected to the linear potentiometer, as is also a 45-volt battery. The voltage from the battery is adjusted so that the voltmeter reading corresponds to the concentration of a known standard solution in the flow-through cell. As unknown solutions are poured in, the voltmeter-printer combination automatically reads and prints the corresponding percentage.

**Boron in halite and anhydritic halite rocks**

F. S. Grimaldi and F. O. Simon (Art. 45) developed a rapid direct spectrophotometric method for determining traces of boron in halite and halite-anhydrite mixtures. The lower limit of detection is 0.1 ppm of boron with a 1-gram sample. The sample is dissolved by fuming with sulfuric acid in an open beaker at a sufficiently low temperature to allow reflux action. No boron is lost by volatilization. The determination is completed spectrophotometrically with dianthrimide. Possible losses of boron through volatilization, surface adsorption, and polymerization were assessed. When a borate solution is evaporated to dryness in etched quartzware, boron is irreversibly adsorbed on the surface, and apparent low recoveries are obtained. This is not observed with smooth quartz. Furthermore, no loss takes place with etched quartz as long as the evaporation is not continued beyond a point where some liquid remains (about 0.2 ml).

**Spectrochemical determination of mercury at very low concentrations**

The method of Sergeev for determining spectrochemically very low concentrations of mercury has been used by P. Barnett for a study of samples from Ely, Nev. The concentration limit of detection is 0.01 ppm. In the procedure a specially designed furnace is used to volatilize mercury from a 10-gram sample directly into a 10-ampere d-c arc.

**Comparator for semiquantitative spectrochemical analysis**

A comparator planned by A. W. Helz and designed and built by C. J. Massoni is being used for the semiquantitative analytical services. The estimate of element concentration is based on a visual comparison of sample spectra with reference spectra. The increased precision of the comparisons required by the extension of the semiquantitative spectrographic procedure to reporting estimates of element concentrations to ⅙ order of magnitude emphasized the need for a better comparator than those commercially available. Chief objectives of the design were high-quality images, × 20 magnification, and the minimization of visual and physical fatigue for the operator.

**Direct-current-arc atmosphere control in spectrochemical analysis**

With the ever-increasing refinements in spectrochemical analysis, more and varied attempts are being made to improve the direct-current arc by control of the arc atmosphere. In Geological Survey Bulletin 1084–J (1961) two gas jets were described which proved very effective for arc control and cyanogen-band depression. This type of jet was modified further by A. W. Helz for use with a modern inclosed arc stand and standard prefabricated electrodes.

## X-RAY FLUORESCENCE ANALYSIS

**Silicate rocks**

The rapid analysis of silicate rocks by X-ray fluorescence has been put on a routine basis. A method for the analysis of the major rock elements Mg, Al, P, Si, K, Ca, Fe, Mn, and Ti has been established and programmed for a nine-channel X-ray quantometer which permits the simultaneous determination of the above elements. The results are comparable in accuracy to those obtained by rapid chemical procedures but may be obtained much more rapidly with substantially smaller samples. The significance of this development is the increase in capabilities for handling larger work loads with much greater efficiency. Current improvements in the procedure by H. J. Rose, Jr., and by L. Shapiro and E. L. Curtis (Art. 103) indicate a possibility of reducing the sample size requirement from about 200 mg to less than 50 mg.

**Iron in hematitic ores**

W. W. Niles used X-ray fluorescence spectroscopy to determine total iron in hematitic iron ores. The iron content of the ore samples ranged from 2 to 45 percent with a coefficient of variation of 1.17 percent. A comparison of results on 10 ores obtained by chemical and

X-ray spectrographic methods indicated an average difference between the two methods of 0.81 percent.

Calcium carbonate, silica, and boric acid are mixed with the powdered sample. A pellet prepared from such a mixture is used for the X-ray fluorescence measurement. Corrections for interference by calcium and silicon are easily made.

## ELECTRON-MICROPROBE STUDIES

### Cosmic particles

There is much interest in the analysis and description of "cosmic particles." These particles, 30 microns and smaller and weighing as little as $10^{-12}$ g, are collected from a number of sources such as the upper atmosphere, deep-sea sediments, icecaps, and from certain high-altitude stations, such as Mount Witthington, N. Mex. The electron probe is ideally suited for the analysis of these particles. The particles are prepared for study with the use of cold-setting epoxy resins and an ultramicrotome, such as that normally used in biological work. Slices of the cured resin containing particles for analysis can be made as thin as $\frac{1}{40}$ of a micron. In addition to obtaining a high yield of successfully prepared particles by this procedure, it also has been possible to slice through individual particles and determine whether they are hollow or solid.

Using the above techniques, R. Larson analyzed five particles collected by Prof. Crozier of the New Mexico Institute of Mining and Technology from the atmosphere at Mount Witthington. Four particles contained approximately 65 percent iron without detectable Ni, Mn, Cr, or Ti—probably magnetite. The fifth particle was hollow, extremely fragile and could not be prepared by this technique. Four magnetic spherules from Ross Ice Cap, Antarctica, were also studied. One was hollow and contained approximately 65 percent iron. Two others had a similar iron content, while the fourth particle had in addition small amounts of Ti and Mn but no detectable Ni. A conclusion that the particles are of terrestial origin is suggested. The work performed points up the need for more controlled sample collection.

### Copper arsenide minerals

An electron-probe study of copper arsenide minerals from Michigan, Colorado, and Bolivia by Cynthia Mead and I. Adler has resulted in qualitative and quantitative chemical analysis of fine intergrowths of $\alpha$ and $\beta$ domeykite, algodonite, and koutekite. Use of the electron probe for this study has eliminated much conflicting information concerning these minerals resulting from the inability of conventional chemical methods to detect chemical changes in micron-sized areas.

## PETROGRAPHIC TECHNIQUES

Minute crystals in the micromicrogram range, occurring in fluid inclusions in quartz from a quartz-chalcopyrite-molybdenite vein in the Bingham copper pit, Utah, have been identified as NaCl by Edwin Roedder. The technique used depends upon their reaction with the surrounding brine solution at low temperatures to form crystals of the new phase $NaCl.2H_2O$. Crystals of NaCl as small as $10^{-12}$ g can be identified with this procedure.

D. D. Dickey and E. F. Monk have found that special procedures are necessary to determine accurately the grain density and porosity of zeolite-bearing rocks. Powdered samples must be soaked in water 3 or 4 days and cores as large as 1 inch in length and 1 inch in diameter must be soaked for 20 days (Art. 46).

Very fine grained mineral samples tend to flocculate in common heavy liquids, thus preventing gravity separations. However, by repeated short high-speed centrifugation, Robert Schoen has been able to obtain good concentrations of minerals of sizes of 10 microns and above. No gravity separation was obtained of 5-micron material.

A technique has been developed by Peter O. Sandvik of the Geological Survey and Ruperto Laniz of Stanford University for preparation of low-relief polished sections of minerals of widely different hardness. A Syntron vibratory polisher is used with alumina abrasives in a water slurry on wax and plastic sufaces. Final polish is in two stages requiring 1½ to 2 hours total time in which up to 15 sections may be prepared simultaneously on a single machine.

A rapid procedure for determining plagioclase has been developed by D. C. Noble, using the five-axis universal stage. Based on the parameters X to $\perp$(010) and Y to $\perp$(010), the method is much faster than the Fedorow method and provides the same information.

## GEOCHEMICAL PROSPECTING

During the year the Geological Survey has developed several geochemical techniques that will be useful in the search for new ore deposits. The exploration of a large buried intrusive mass near Ruth, Nev., by a combination of geologic, geophysical, and geochemical techniques by Brokaw and others (1–62, 2–63) is described on page A3. The use of variations in the isotopic composition of oxygen and carbon in prospecting for ore in carbonate rocks, by Lovering and others (Art. 1), is discussed on page A6.

### Compilation of geochemical prospecting methods

F. N. Ward, H. W. Lakin, F. C. Canney, and others (1–63) have prepared a compilation of trace and semimicroanalytical methods yielding semiquantitative data on geologic materials useful in geochemical prospecting for ore deposits. Chemical methods for 24 elements are described in sufficient detail to permit use by relatively nontechnical persons. These elements are as follows: antimony, arsenic, barium, bismuth, chromium, cobalt, copper, germanium, iron, lead, manganese, mercury, molybdenum, nickel, niobium, phosphorus, selenium, sulfur, tin, titanium, tungsten, uranium, vanadium, and zinc. Some of these methods are modifications of methods developed in laboratories abroad; others were developed originally in U.S. Geological Survey laboratories. A few are modifications of well-known analytical procedures.

#### Geochemical mapping in Maine

A geochemical mapping program in west-central Maine under the direction of E. V. Post resulted in the collection of 2,300 samples of stream sediment from an area of about 5,000 square miles. The data on the content of copper, lead, zinc, nickel, and cold-extractable heavy metals of these samples have allowed the recognition of six patterns of anomalous metal values. These are, in order of increasing significance to mineral exploration: (1) scattered isolated high copper or heavy-metals values with no apparent relation to geology; (2) groups of high heavy-metals values apparently related to precipitates of hydrous manganese-iron oxides in the stream courses; (3) groups of high nickel values related to ultramafic phases of mafic intrusives, and probably indicative of normal abundance of nickel in that type of rock; (4) groups of either high copper or high heavy-metal values, or both, that are associated with stratigraphic units of tuffs, volcanic rocks, and mafic dikes and sills; (5) groups of high values similar to (4) but peripheral to plutonic rocks of intermediate composition; and (6) groups of high copper values and variable heavy-metals values related to known copper deposits in schistose felsic volcanic rocks of Ordovician(?) age.

#### Minor elements in stream waters

Data of especial interest to individuals conducting geochemical-prospecting drainage surveys are contained in the report by Theobald, Lakin, and Hawkins (1–63) on the precipitation of aluminum, iron, and manganese at the junction of Deer Creek with the Snake River in Summit County, Colo. Their studies on the distribution of minor elements in the stream waters and stream sediments illustrate that potentially misleading chemical patterns can develop at the confluence of two streams with waters of widely dissimilar chemical composition.

#### Neutron-activation and gamma-ray spectrometry

C. M. Bunker reports that whole-rock samples are being analyzed by neutron-activation and gamma-ray spectrometry to evaluate the limitations of the technique and to devise methods of making rapid quantitative analyses of elements not amenable to other techniques. Long-lived elements are particularly amenable to this technique. Future work will be applied to studies of trace elements related to ore deposits.

#### Portable beryllium detector

A portable beryllium detector with an activating gamma source was constructed by W. W. Vaughn. The use of this instrument by C. L. Sainsbury aided in a beryllium discovery in Alaska. The determination of beryllium is based on the photo-neutron reaction $^{9}Be(\gamma, N)^{8}Be$. $^{124}Sb$ is used as a $\gamma$ source and a $BF_3$ proportional counter as a neutron detector.

## ANALYSIS OF WATER

#### Arsenic

G. Stratton and H. C. Whitehead (1–62) developed an extremely sensitive and accurate method for the determination of arsenic in water. The method, which is based on the spectrophotometric measurement of the intense red color formed when arsine is bubbled through a solution of silver diethyldithiocarbamate dissolved in pyridine, is capable of detecting as little as 1 $\mu$g of arsenic in 35 ml of sample.

#### Bromide

A rapid, accurate, and sensitive indirect spectrophotometric method for the determination of trace amounts of bromide ion in water has been developed by M. J. Fishman and M. W. Skougstad (1–63). Bromide ion catalyzes the oxidation of iodine to iodate by permanganate in acid solution, the extent of oxidation being proportional to bromide concentration for a given time and for a given set of conditions of temperature, pH, and concentration of reagents. The method is applicable to bromide concentrations ranging from 1 to 100 $\mu$g per liter and is not subject to interference from most substances normally occurring in natural water.

#### Preparation of water samples for $C^{14}$ dating

An assessment of the age of water in various parts of hydrologic systems is useful in determining both the direction and rate of water movement. An adequate, yet simple, field procedure for isolating total dissolved carbonate species from water to provide samples for $C^{14}$ dating has been devoloped by H. R. Feltz and B. B. Hanshaw. The method provides a convenient means for handling the relatively large volumes of water frequently needed in order to provide the minimum of 3 g of carbon required by the counting laboratory. Dissolved carbonate species are liberated by the addition of $H_2SO_4$, and the evolved gases are collected in a NaOH trap by recycling in a closed system. Strontium chloride solution is then added to the caustic-carbonate solution in the trap, and the resulting strontium-carbonate precipitate is filtered, washed, and dried in preparation for $C^{14}$ counting.

### Spectrographic methods of analysis for rare alkalies and alkaline earths

Methods for emission-spectrographic determination of rubidium, cesium, strontium, and barium in water samples have been developed by V. H. Stone. Using special precipitating agents, sodium tetraphenylboron for rubidium and cesium, and potassium rhodizonate for strontium and barium, these elements are separated from the major constituents usually found in natural waters. The collected precipitates are subsequently subjected to emission-spectrographic analysis using a d-c arc operating in an oxygen atmosphere; lanthanum is added as an internal standard. The detection limits are 0.5 $\mu g$ for strontium, 1 $\mu g$ for barium, 5 $\mu g$ for rubidium, and 200 $\mu g$ for cesium.

### Total-sulfur determination by neutron activation

C. H. Wayman demonstrated that total sulfur in water can be determined by neutron-activitation analysis utilizing the $S^{32}$ (n, p) $P^{32}$ reaction. Chlorine and phosphorus interfere and must be removed prior to irradiation. The detection limit is 0.01 ppm of sulfur.

### Vanadium

An extremely sensitive catalytic method for the determination of vanadium in water has been developed by M. J. Fishman. Vanadium concentrations of less than 1 $\mu g$ per liter can be determined by measuring the extent of oxidation of gallic acid by persulfate ion in acid solution, a reaction which is catalyzed by the presence of minute amounts of vanadium.

### Improved method for chloride and nitrate titration

An improvement in the accuracy and precision of routine mercurimetric chloride titrations has been achieved by G. F. Scharbro, Jr., who modified a simple colorimeter to adapt it for use in spectrophotometric titrations. An improved nitrate method has also been developed which is not affected by the presence of chloride ion in the sample. Nitrate, after reduction to nitrite by hydrazine in alkaline solution, is determined by measuring the intensity of the color formed in the sensitive nitrate-diazotization-coupling reaction with nitrate, sulfanilamide, and naphthylethylene diamine. Nitrite, if present in the original sample, is removed by a preliminary extraction with an isoamyl alcohol-carbon tetrachloride mixture.

### Tritium-counting technique

Several gases have been investigated by G. L. Stewart and C. M. Hoffman for suitability as quenching agents in gas-phase counting systems used to measure tritium in low-level samples. At high hydrogen pressures, ethylamine was found to have quench properties superior to toluene, isoprene, diethyl ether, and ethylene. At high hydrogen: ethylamine ratios, the Geiger plateaus were short with steep slopes, but as the ratio decreased the plateaus lengthened and the slopes decreased. An optimum counting mixture of 10:1 hydrogen to ethylamine pressure ratio was found. This ratio gave long plateaus of approximately 500 volts and excellent slope characteristics. Ethylamine has the advantage of being a high-vapor-pressure liquid (760 mm Hg at 16.6°C), which permits it to be used in high-pressure counting mixtures.

### Computer program for dissolved-oxygen data

A computer program was developed by F. B. Sower for processing large amounts of data collected in studies of organic production of oxygen in water bodies. This program is sufficiently flexible to accept all Winkler-method data for which sample and aliquot volumes, normality of titrant, sample temperature, and barometric pressure are known. The output is in dissolved-oxygen concentration and percent saturation at the temperature and elevation (pressure) of the sample at sea level. Provision is made for deriving solar-radiation values in cal per $cm^2$ per min from pyrheliometer readings, in millivolts.

### Characterization of carboxylic acids in unpolluted streams

W. L. Lamar and D. F. Goerlitz (1–63) have described the separation and identification of carboxylic acids in unpolluted surface water. The organic matter in each sample was concentrated from 23.5 liters of water by continuous liquid-liquid extraction using n-butanol as a solvent and (or) by vacuum evaporation at 50°C. The carboxylic acids were separated from the other organic components by differential solubility and pH. The isolated carboxylic acids were separated into two groups, steam-volatile acids and the higher boiling acids, and analyzed by gas chromatography. Since the latter acids are not sufficiently volatile or stable for gas chromatographic examination, they were converted into methyl esters. Twenty carboxylic acids were isolated by gas chromatographic analysis of which 12 were identified, namely acetic, adipic, butyric, caproic, fumaric, lactic, maleic, malonic, oxalic, propionic, succinic, and valeric.

## HYDROLOGIC MEASUREMENTS AND INSTRUMENTATION

Much progress was made during the year on applications of nuclear detectors to measurement of soil moisture and movement of ground water. Several new or improved instruments and techniques for measuring sediment transport were developed. Sensitive instruments developed for use in other fields were modified for application to hydraulic or hydrologic measurements. Substantial progress was made on automation of data collection and analysis.

### Radioactivity detector developments

A. O. Waananen used access tubes sealed at the bottom end and inserted in small-diameter ground-water observation wells for observation of moisture content, with the neutron-scattering meter in the zone of water-table fluctuations. Variations in observed moisture content of the aquifer between high and low water levels provide a measure of the aquifer storage capacity. Calibration of the access tube and observation-well casing is necessary. Waananen reports optimum results when the observation-well casing is only slightly larger than the access tube and a 10-mg or larger neutron source is used.

O. E. Leppanen and T. E. A. van Hylckama investigated the accuracy of calibration of neutron-scattering soil-moisture meters at a site near Buckeye, Ariz., in the summer of 1962. Three 10-foot soil moisture tubes were installed, and the ground surrounding 2 tubes was soaked for 2 weeks prior to the test to attain a wide range in moisture. Calibration was made by comparison with core samples taken at 25-cm intervals at 5 holes ringing each soil-moisture tube. Because calibrations for two similar soil-moisture meters showed a high degree of linearity, it may be feasible to log by moving the probe at constant velocity from top to bottom. The tests also showed the effect of chloride, in the soil water, on the calibration.

Satisfactory test of a combination tracer-ejector probe for determination of the direction and rate of ground-water flow in a borehole in basalt was reported by D. A. Morris. The probe permits ejection of a radioactive tracer into ground water in a borehole and detection of the tracer movement with a scintillation crystal in the gamma section of the probe.

### Permeameter for measuring directional permeability differences

R. R. Bennett has designed a sensitive differential permeameter for measuring the directional permeability properties of consolidated porous media. The permeameter is analogous to a wheatstone bridge, in that microvalves form three arms and the porous sample the fourth. A highly sensitive pressure transducer meter is the null-measuring device. The permeameter has passed initial tests.

### Fluorescent mineral grains used as tracers in sediment movement

Fluorescent wernerite is being used for tracing sediment movement in flume experiments by V. C. Kennedy, D. W. Hubbell, and others. The brilliant fluorescence of wernerite under longwave ultraviolet radiation permits photography of the movement of individual grains either in plan or section. Wernerite particles apparently mix uniformly with the nonfluorescent grains within a short distance from the point of introduction. The sediment load may be estimated from samples taken downstream from the point of introduction of the tracer, by determining the dilution of tracer grains in each size fraction of the samples.

### Sediment sampling

B. C. Colby designed a suspended-sediment sampler to replace the US P–46 sampler now in general use. The new sampler, the US P–61, is more rugged, more dependable, less expensive, and simpler to operate and maintain than the US P–46 sampler. It is expected that more than 100 of the new samplers will be purchased and used by Federal agencies in the next few years.

G. F. Flammer has developed ultrasonic equipment that can measure the size and concentration of sediment in samples. Tests of the equipment are being conducted to evaluate its use in routine laboratory analysis.

Two devices for aiding in maintaining a constant transit rate during depth-integrated sediment sampling have been developed by J. V. Skinner and B. C. Colby. One device furnishes light flashes at preset intervals with which the operator synchronizes revolutions of the sampling reel. The second device incorporates a tachometer-generator with a voltmeter calibrated to indicate transit rate.

Tests of the intermittent-pumping sampler reported by H. H. Stevens, Jr., and B. C. Colby (U.S. Geol. Survey Prof. Paper 450–A, p. A123) have shown satisfactory results for suspended sediments of silt and clay sizes and are continuing to establish accuracy of sampling in the sand sizes.

An investigation of the Texas-type sediment sampler, using the U.S. depth-integrating sampler as standard, has shown that results are about the same for both samplers for streams in which the sediment is more than 85 percent silt and clay. C. T. Welborn reports that for streams in which the sediment contains more than 15 percent sand the Texas-type sampler concentrations must be corrected by a coefficient greater than 1 and for streams in which the sediment is 50 percent or more sand, the correction coefficient ranges from 1.5 to 2.0.

#### New in-place soil-moisture sensor

I. S. McQueen and R. F. Miller are developing a sensor for soil-moisture tension in place. A miniature sensing unit that is exposed only to the soil atmosphere responds to changes in moisture tension over the full tension range. The new instrument is expected to eliminate shifts in the moisture-tension calibration curve caused by salts in the soil solution.

#### Sensitive transducer detects minute water-level variations

J. A. da Costa and B. J. Bermes have developed a highly sensitive transducer for detecting minute variations, caused by seismic waves, in water levels in artesian wells. Temperature effects which cause undesirable noise at all frequencies have been eliminated without the use of electronic filtering devices. Short-period atmospheric-pressure fluctuations are minimized by electronically subtracting the indications from an identical transducer subjected to only atmospheric-pressure variations. The equipment has detected seismic waves from several distant nuclear tests.

#### Refined instrumentation for glacial water budget

Instrumentation has been developed by M. F. Meier and W. V. Tangborn to record changes in the water budget as a function of time for a high-altitude drainage basin containing South Cascade Glacier, Wash. This instrumentation includes a stream-gaging station, with covered control, built to function under a 20-foot snowpack, a recording precipitation gage built to function under any weather conditions, several recording thermographs, and a number of nonrecording instruments of unique design. The recording instruments are capable of unattended operation for as long as 6 months. The data collected will permit calculation of such previously unknown quantities as the relative contribution to runoff of snowmelt, icemelt, direct precipitation, and base flow from ice and ground; the varying storage of water in snow and ice; the transfer of mass from slopes to the trunk glacier by avalanches and wind; and the hydrologic peculiarities of streamflow from a glacier in winter.

#### Television camera for use in water wells

J. E. Eddy has developed a television camera that permits down-hole inspection of borehole or casing in water wells. The view scanned by the camera is displayed on a picture tube at the surface.

#### Nomogram for heat-flow computations

A nomogram with adjustable scales has been developed by T. E. A. van Hylckama and O. E. Leppanen to speed up heat-flow computations derived from thermopile voltages, temperatures, and calibration constants.

#### Automation of water-quality data

A system for automatic tabulation of water-quality data using Flexowriter, 046 IBM tape-to-card converter, 026 IBM printing key punch, and 407 IBM accounting machine is reported by G. A. Billingsley. Punch cards for computation of weighted averages, frequency distribution, means, medians, modes, ranges, variance, and special reports for water-quality data are being utilized.

#### Automation of stream gaging

The use of digital recorders at stream-gaging stations has grown during the last year from the field-testing phase to fully operational phase. W. L. Isherwood reports that about 700 gaging stations from New England to Hawaii are now so equipped. An improved system adopted October 1962 provides for complete automatic processing beginning with the punched tapes from the recorders and ending with camera copy for offset printing.

#### Automated water-quality monitoring

After several years of development and testing on the Delaware River, N. H. Beamer reports a supersensitive instrumentation system that automatically samples and continuously records water-quality information along the Philadelphia waterfront. This "sentinel", which is a major breakthrough in instrumentation for marine studies, has a submerged pump which distributes representative river water to five transistorized sensors that test the temperature, turbidity, electrical conductivity, dissolved-oxygen content, and pH. The data can be telemetered for instant recording elsewhere.

#### Continuous recording measurements of radioactivity and bulk density of bottom sediments

C. M. Bunker has directed the design and field testing of equipment for mapping radioactivity and relative bulk density of recent ocean and lake sediments. Measurements are made by towing the detection equipment along the surface of the sediments behind a vessel. Data are transmitted in the form of electrical pulses from the detectors through a coaxial cable to equipment on the vessel, where they are converted to strip-chart records. Tests during 1962 on bottom sediments of Burt Lake in Michigan were successful.

### Automatic-recording precise tiltmeter

An automatic-recording liquid-level tiltmeter has been developed by Francis S. Riley. The instrument traces a continuous record of differential elevation changes between points as much as 100 meters apart, with a maximum sensitivity of 25 millimicrons per millimeter of pen displacement. Useful response to oscillatory tilting is obtained at frequencies up to 2 cycles per minute. The equipment is portable and can be operated in the field with minimum site preparation. Although developed primarily to record micromovements of the land surface around a pumped artesian well, especially in areas of active land subsidence, the instrument may find considerable application to other problems in the fields of geophysics and engineering geology.

708-043 O—63——13

# TOPOGRAPHIC SURVEYS AND MAPPING

## MAPPING ACCOMPLISHMENTS

### Objectives of the National Topographic Mapping Program

The major function of the Topographic Division of the U.S. Geological Survey is the preparation and maintenance of the National Topographic Map Series covering the United States and outlying areas. This map series, comprising several series of quadrangle maps at different scales, is a fundamental part of the background research required to inventory, develop, and manage the natural resources of the country. Other divisional functions are the production of related maps; periodic revision and maintenance of maps and publications; and research to improve map products, engineering techniques, and instrumental equipment.

In addition to the maps described below, the Topographic Division prepares shaded-relief maps, U.S. base maps, special maps, and also a few planimetric maps.

Procedures for obtaining copies of the maps and map products of the Survey are given on page A198.

### Series and scales

All topographic surveys, except those in Alaska, are being made to standards of accuracy and content required for map publications at a scale of 1:24,000. Initial publication may be either at a scale of 1:24,000 or 1:62,500, depending on the need. If 1:62,500-scale maps are published initially, the 1:24,000-scale surveys in the form of photogrammetric compilation sheets are available on open file, and for future publication at that scale. For maps in Alaska the publication scale is 1:63,360 or "inch-to-the-mile."

### Coverage of the Nation

Fifty seven percent of the total area of the 50 states, Puerto Rico, and the Virgin Islands (fig. 7) is covered by published standard quadrangle maps at scales of 1:24,000, 1:62,500, and 1:63,360 (for Alaska only). An additional 9 percent of the total area is covered by topographic surveys at these scales, which are available on open file as unpublished maps.

During fiscal 1963, 543 maps were published covering previously unmapped areas equal to 1.6 percent of the total area. An additional 439 new maps, at a scale of 1:24,000, equivalent to 0.7 percent of the total area, were published to replace maps of 15-minute quadrangles (scale 1:62,500) compiled to obsolete standards. For the extent and location of map coverage, see figure 8.

### Map revision and maintenance

During 1962, about 56,000 square miles of 7½-minute mapping was added to the growing backlog of maps in need of revision. During fiscal 1963, the backlog was diminished by revising about 10,400 square miles of mapping, leaving about 318,500 square miles of 7½-minute mapping in need of revision at the end of the year (fig. 9).

### 1 : 250,000-scale mapping

The 48 conterminous States and Hawaii are 99 percent covered by 1:250,000-scale maps originally prepared as miiltary editions by the Army Map Service. As these maps are completed, certain changes and additions are made to make them more suitable for civil use and for distribution to the public. The revision and maintenance of this series is to be carried out by the Topographic Division. Maps of Alaska at this scale are being prepared and published by the Geological Survey. Coverage of the 50 States, Puerto Rico, and the Virgin Islands by 1:250,000-scale maps and the work in progress are shown on figure 10.

### State maps

State maps are published at scales of 1:500,000 and 1:1,000,000, except for Alaska, which is covered by base maps published at scales of 1:1,584,000 and 1:2,500,000, and Hawaii, which is not yet covered by any of these maps.

Twenty-seven maps covering 31 States and the District of Columbia, compiled to modern standards, have been published in a new series entailing as many as four editions: base, base and highways, base and highways and contours, and shaded relief on a modified base. As shown on figure 11, other conterminous States are covered by an earlier series.

### Metropolitan areas

Metropolitan-area maps are prepared by combining on one or more sheets the 7½-minute quadrangles that cover a metropolitan area. Maps of 56 metropolitan areas have been published, including 2 new and 2 revised maps that were completed during fiscal 1963. Work in progress includes 2 new maps and the revision of 4 others.

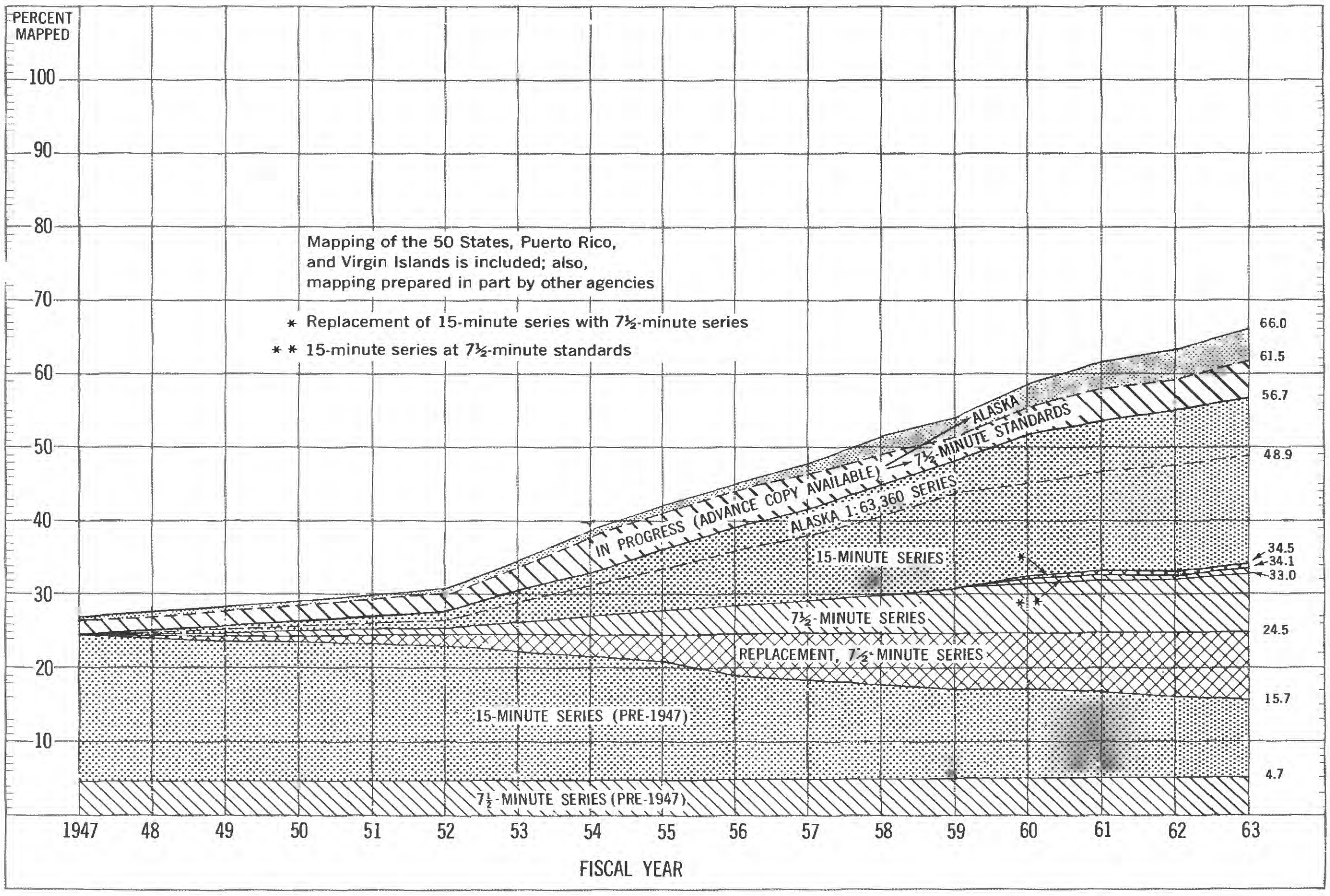


FIGURE 7.—Progress of 7½- and 15-minute quadrangle mapping.

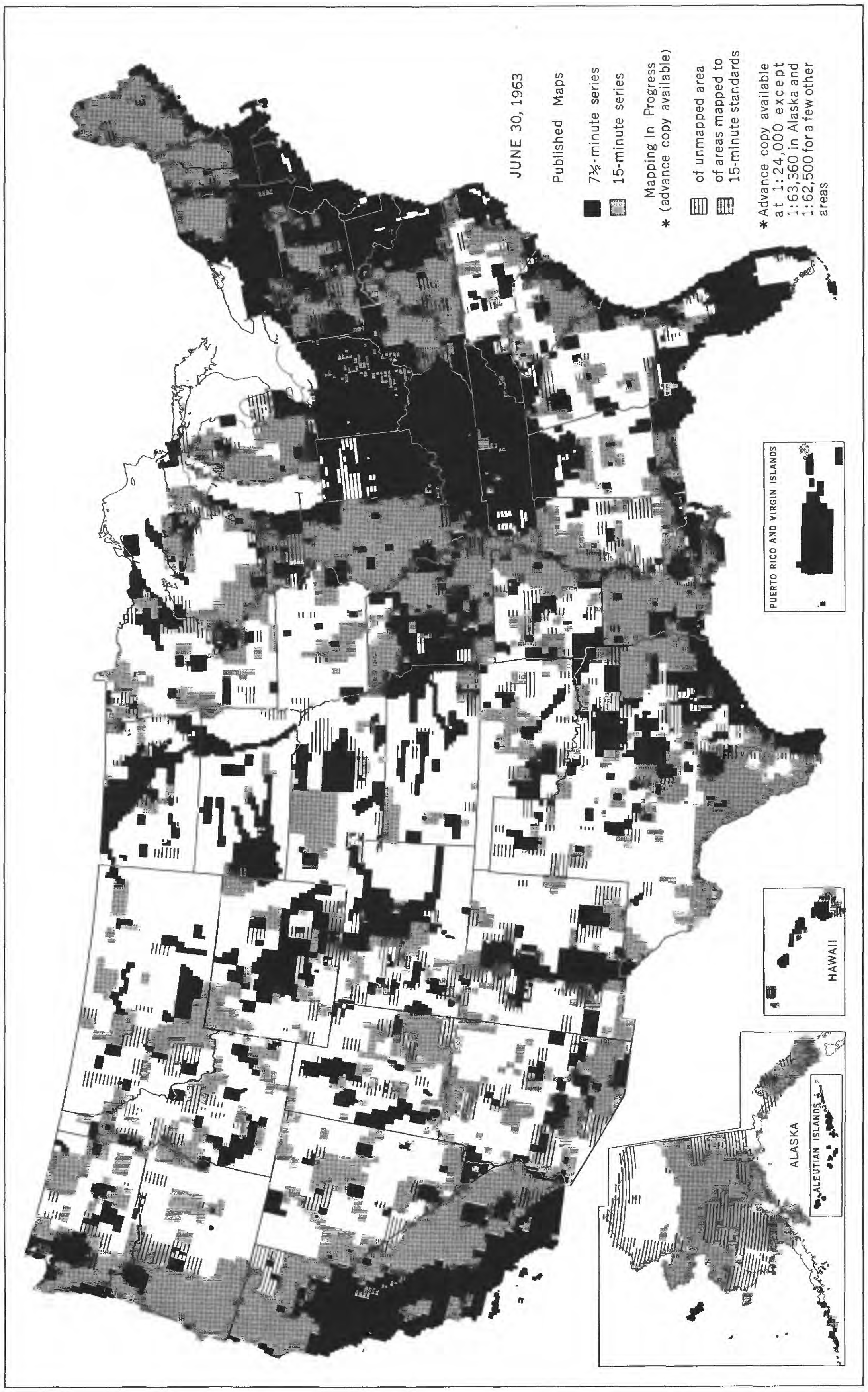


FIGURE 8.—Status of 7½- and 15-minute quadrangle mapping.

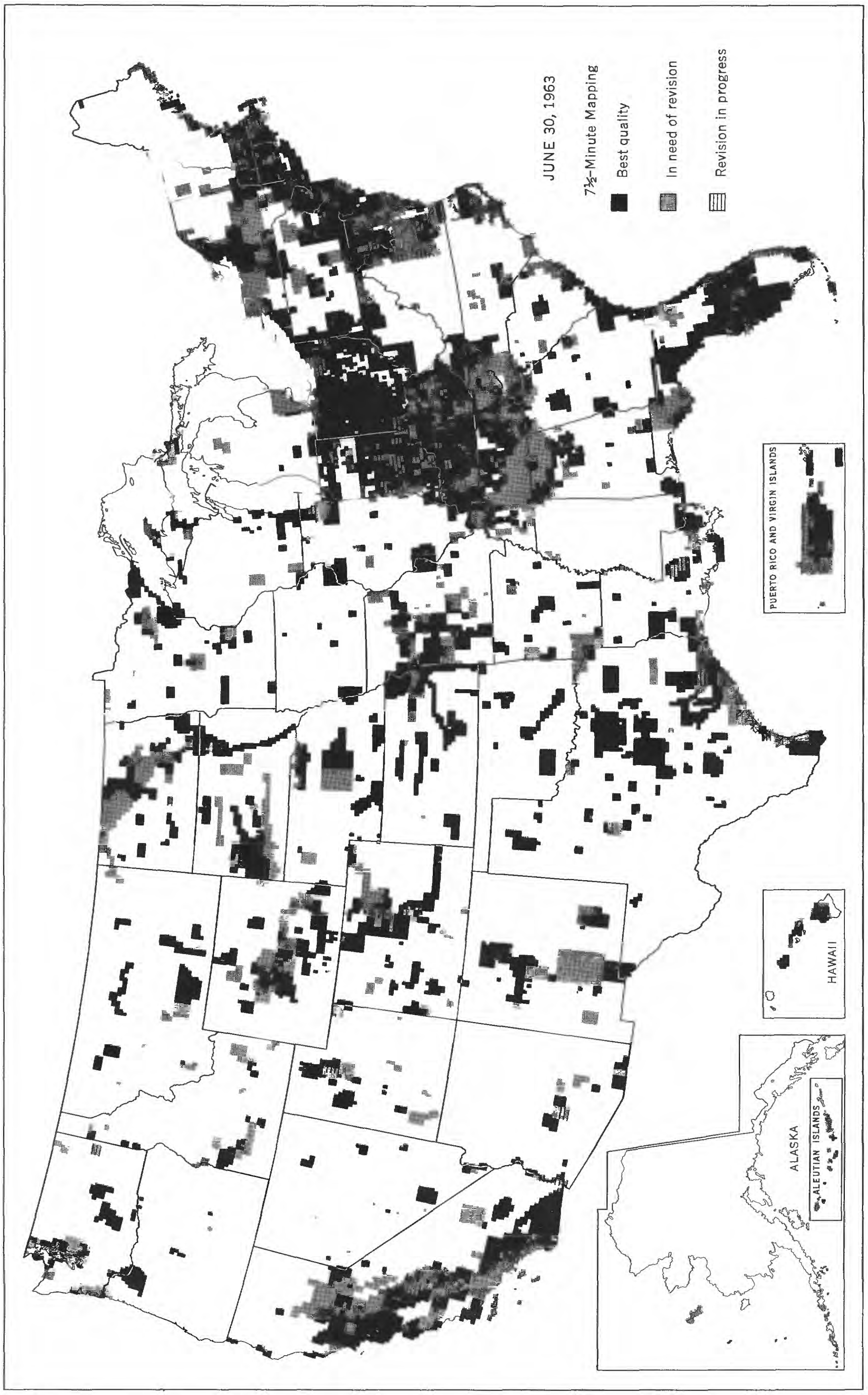


FIGURE 9.—Status of revision of large-scale mapping.

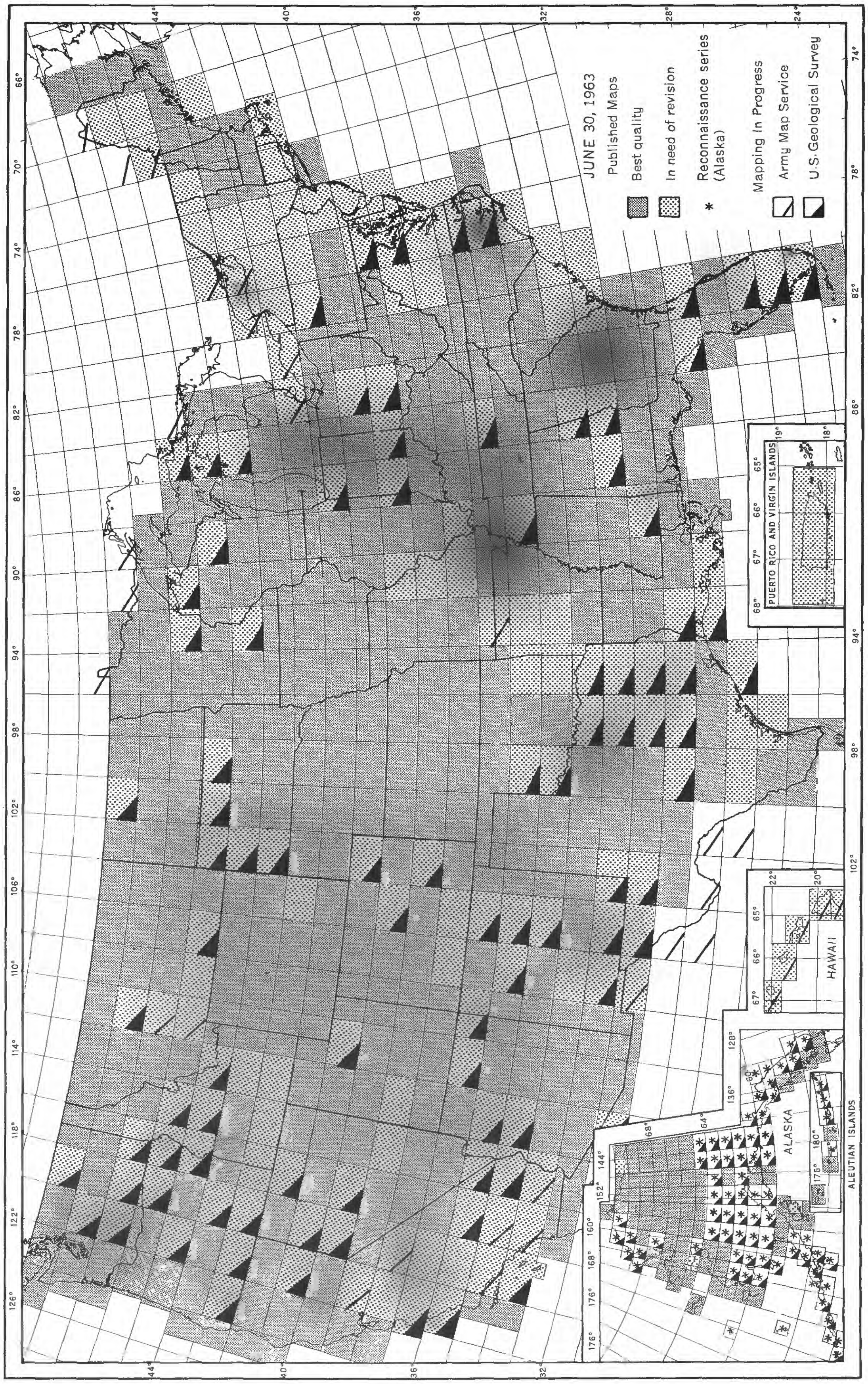


FIGURE 10.—Status of 1:250,000-scale mapping.


FIGURE 11.—Status of State maps.

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Albuquerque, N. Mex.
Atlanta, Ga.
Austin, Tex.
Baton Rouge, La.
Boston, Mass.
Bridgeport, Conn.
Buffalo, N.Y.
Champaign-Urbana, Ill.
Chattanooga, Tenn.
Chicago, Ill. (3 sheets)
Cincinnati, Ohio
Cleveland, Ohio
Columbus, Ohio
Davenport-Rock Island-Moline, Iowa and Illinois
Dayton, Ohio
Denver, Colo.
Detroit, Mich. (2 sheets)
Duluth-Superior, Minnesota and Wisconsin
Fort Worth, Tex.
Gary, Ind.
Hartford-New Britain, Conn.
Honolulu, Hawaii
Houston, Tex.
Indianapolis, Ind.
Juneau, Alaska
Knoxville, Tenn.
Little Rock, Ark.
Los Angeles-Long Beach, Calif. (3 sheets)
Louisville, Ky.
Madison, Wis.
Milwaukee, Wis.
Minneapolis-St. Paul, Minn.
New Haven, Conn.
New Orleans, La.
New York, N.Y. (8 sheets)
Norfolk-Portsmouth-Newport News, Va.
Oakland, Calif.
Peoria, Ill.
Philadelphia, Pa. (2 sheets)
Pittsburgh, Pa.
Portland-Vancouver, Oregon and Washington
Rochester, N.Y.
Salt Lake City, Utah
San Diego, Calif.
San Francisco, Calif.
San Juan, P.R.
Seattle, Wash.
Shreveport, La.
Spokane, Wash.
Toledo, Ohio
Washington, D.C.
Wichita, Kans.
Wilkes-Barre-Pittstown, Pa.
Wilmington, Del.
Worcester, Mass.
Youngstown, Ohio

IN PROGRESS

*New Maps*
Anchorage, Alaska
Tacoma, Wash.

*Revision*
Cincinnati, Ohio
Louisville, Ky.
Portland-Vancouver, Oregon and Washington
Washington, D.C.

## National park maps

Maps of 44 of the 184 national parks, monuments, historic sites, and other areas administered by the National Park Service have been published. These usually are made by combining all existing quadrangle maps into one map sheet, but occasionally surveys are made covering only the park area. Published maps in this series include:

Acadia National Park, Maine
Bandelier National Monument, N. Mex.
Black Canyon of the Gunnison National Monument, Colo.
Bryce Canyon National Park, Utah
Canyon de Chelly National Monument, Ariz.
Carlsbad Caverns National Park, N. Mex.
Cedar Breaks National Monument, Utah
Chickamauga and Chattanooga National Military Park, Ga.
Colonial National Historical Park (Yorktown), Va.
Colorado National Monument, Colo.
Crater Lake National Park and Vicinity, Oreg.
Craters of the Moon National Monument, Idaho
Custer Battlefield, Mont.
Devils Tower National Monument, Wyo.
Dinosaur National Monument, Utah-Colorado
Franklin D. Roosevelt National Historic Site, N.Y.
Glacier National Park, Mont.
Grand Canyon National Monument, Ariz.
Grand Canyon National Park, Ariz. (2 sheets)
Grand Teton National Park, Wyo.
Great Sand Dunes National Monument, Colo.
Great Smoky Mountains National Park, North Carolina and Tennessee (2 sheets)
Hawaii National Park, Hawaii (2 sheets)
Hot Springs and Vicinity, Ark.
Isle Royale National Park, Mich.
Lassen Volcanic National Park, Calif.
Mammoth Cave National Park, Ky.
Mesa Verde National Park, Colo.
Mount McKinley National Park, Alaska
Mount Rainier National Park, Wash.
Olympic National Park and Vicinity, Washington
Petrified Forest National Monument, Ariz.
Rocky Mountain National Park, Colo.
Scotts Bluff National Monument, Nebr.
Sequoia and King's Canyon National Parks, Calif.
Shenandoah National Park, Va. (2 sheets)
Shiloh National Military Park, Tenn.
Vanderbilt Mansion National Historic Site, N.Y.
Vicksburg National Military Park, Miss.
Wind Cave National Park, S. Dak.
Yellowstone National Park, Wyoming, Montana, and Idaho
Yosemite National Park, Calif.
Zion National Park (Kolob Section), Utah
Zion National Park (Zion Canyon Section), Utah

## Million-scale maps

The worldwide million-scale series of topographic quadrangle maps was originally sponsored by the International Geographical Union and designated the International Map of the World on the Millionth Scale (IMW). The conterminous United States will be covered by 53 maps, 17 of which were produced before 1955. At that time the Army Map Service began military series at 1:1,000,000 scale. Eventually these AMS maps will be modified slightly and published in the IMW series (fig. 12).

Two of the maps, Hudson River and San Francisco Bay, are no longer available as IMW maps but the areas are covered by AMS maps. Both the IMW and AMS series are available for Boston, Chesapeake Bay, Hatteras, Mississippi Delta (White Lake-AMS), Mt. Shasta, and Point Conception. In addition, the American Geographical Society has published the Sonora, Chihuahua and Monterrey maps, and Canada, the Regina and Montreal maps. Puerto Rico is covered by two maps, each compiled and published by the American Geographical Society and the Army Map Service.

During fiscal 1963, nine maps of the military series were reprinted in format conversions. They conform to the IMW sheet lines and sheet numbering system but do not meet IMW specifications in all respects. They

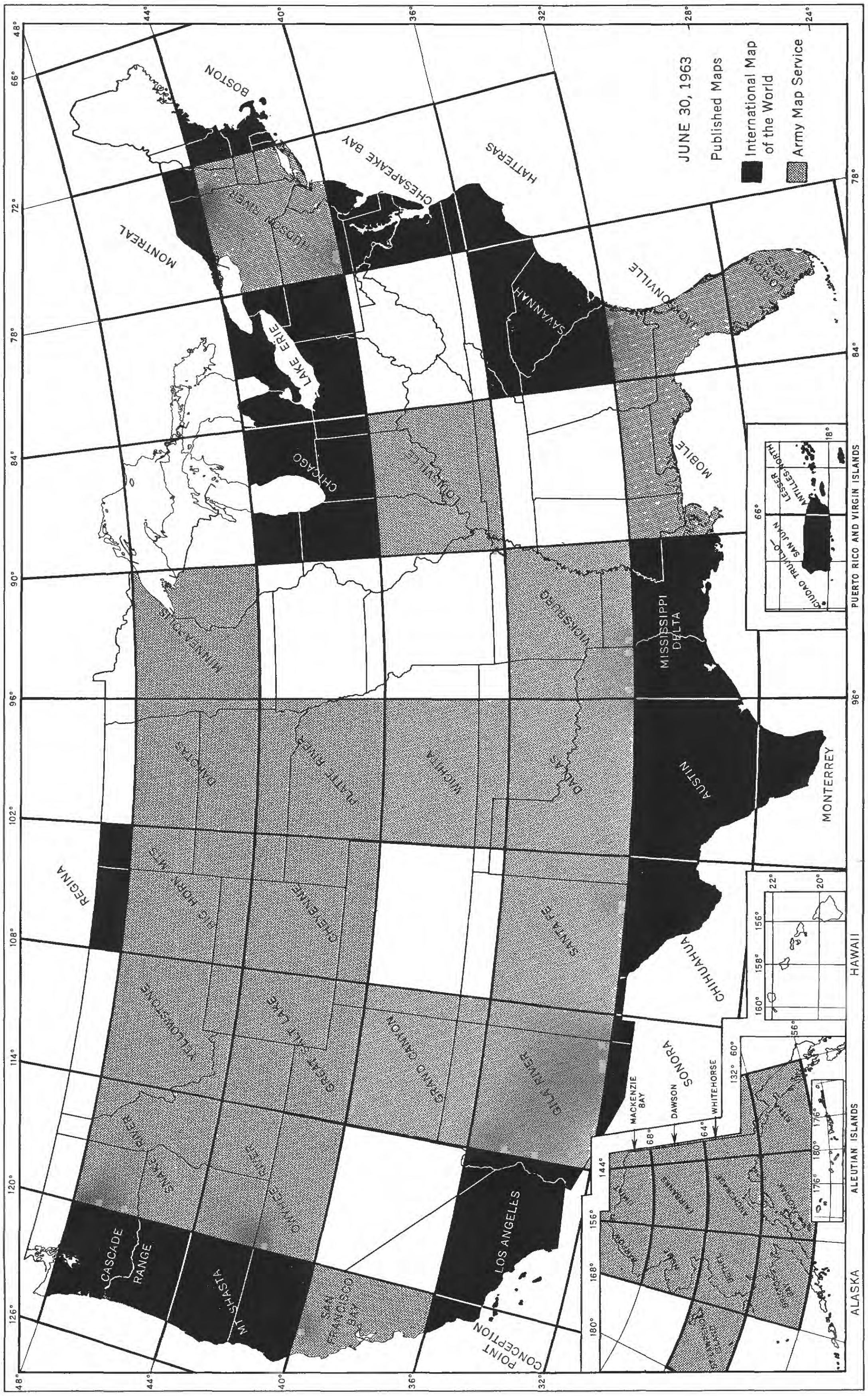


FIGURE 12.—Status of 1:1,000,000-scale topographic maps.

are, however, recognized by the United Nations Cartographic Office as provisional editions in the IMW series.

## MAPPING IN ANTARCTICA

The topographic mapping of Antarctica, carried on as part of the U.S. Antarctic Research Program (USARP) of the National Science Foundation, was expanded during fiscal 1963. Seven topographic engineers went to Antarctica during the austral summer of 1962–63 to obtain geodetic control for topographic mapping, and a specialist in aerial photography was assigned to Christchurch, New Zealand, for photographic liaison duty with the Navy.

### Topographic field operations

P. F. Bermel, D. C. Barnett, K. S. McLean, and E. R. Soza used electronic distance-measuring equipment to establish mapping control in North Victoria Land and in the mountains between the Beardmore Glacier and the Ohio Range of the Horlick Mountains. In addition to logistical support furnished to all USARP field parties by the U.S. Navy, this group was closely supported by a U.S. Army helicopter detachment. The 1,600-mile traverse established control for mapping 90,000 square miles of mountainous terrain.

While operating with a USARP party fielded by the University of Minnesota, R. M. Collier and D. T. Edson used electronic distance-measuring equipment to establish mapping control in the Heritage and Sentinel Ranges of the Ellsworth Mountains. Vinson Massif, believed to be the highest point in Antarctica, was observed by this party, and a more accurate elevation for this feature is expected to result from computation of the field data.

T. E. Taylor, with a USARP party of Geological Survey geologists, established mapping control in the Pensacola Mountains, using observations on both sun and stars. Taylor also used a phototheodolite to establish additional mapping control.

Stellar observations for geodetic positions were made at critical points along traverse routes, as well as at the South Pole station and at McMurdo station. Control for large-scale mapping was established at the Cape Crozier penguin rookery, and a geodetic traverse was run linking old Byrd station, new Byrd station, and Byrd Delta Sub-One, the auroral satellite observing station.

### Aerial photography

U.S. Navy Air Development Squadron Six obtained aerial photography for mapping in accordance with Geological Survey specifications. W. R. MacDonald was assigned to the Navy Photographic Laboratory at Christchurch, New Zealand, to advise on the quality of developed photography and to assist with the planning and necessary reflights.

Camera malfunctions and logistic difficulties associated with the operating range of the Neptune P2V airplanes used for Antarctic photographic missions limited the success of the aerial photography program. Final analysis of the season's photography indicates that areas totaling about 44,000 square miles were photographed acceptably for use in the Geological Survey mapping program.

### Cartographic activities

Six 1:250,000-scale topographic maps of the Thiel Mountains, Executive Committee Range, and portions of the Horlick Mountains, were published in shaded-relief editions, making a total of 9 sheets at this scale now available. Mapping at the same scale is now underway for 4 additional sheets in the Horlick Mountains, 8 in the Queen Alexandra Range, 6 in the Britannia Range, and 6 covering the McMurdo Sound area (fig. 13).

Uncontrolled planimetric map manuscripts were compiled of part of the Pensacola Mountains, and of the Heritage Range of the Ellsworth Mountains. A sketch map was made of a 20-mile-wide area along the Oates Coast, from Cape Adare, north of Hallett Station, to the Wilson Hills.

### Antarctica relief model

A contract was completed for a 2-layer multicolored plastic relief model of Antarctica, at a scale of 1:10,000,000, with a vertical exaggeration of 25:1. The lower part of the model shows the submarine floor, the sub-ice topography, and ice-free mountain areas on the continent. The upper and removable section of the model, which is transparent, shows the sea-level surface and the surface of the continental ice mass. The projections of mountain masses through the ice also are shown on the upper section. A limited number of these models have been made for purposes of assisting in scientific studies.

## RESEARCH AND DEVELOPMENT

The Geological Survey program of topographic mapping of the United States is supported by continuing research and development of new techniques, instruments, and media. The chief objectives of this research are to improve the quality and usability of topographic maps and to reduce the cost of their preparation. As part of the research effort the Survey carries on an accuracy-testing program, in which a representative 10 percent of the quadrangles mapped is tested by special surveys for precision of position and elevation. The test findings are a valuable guide for

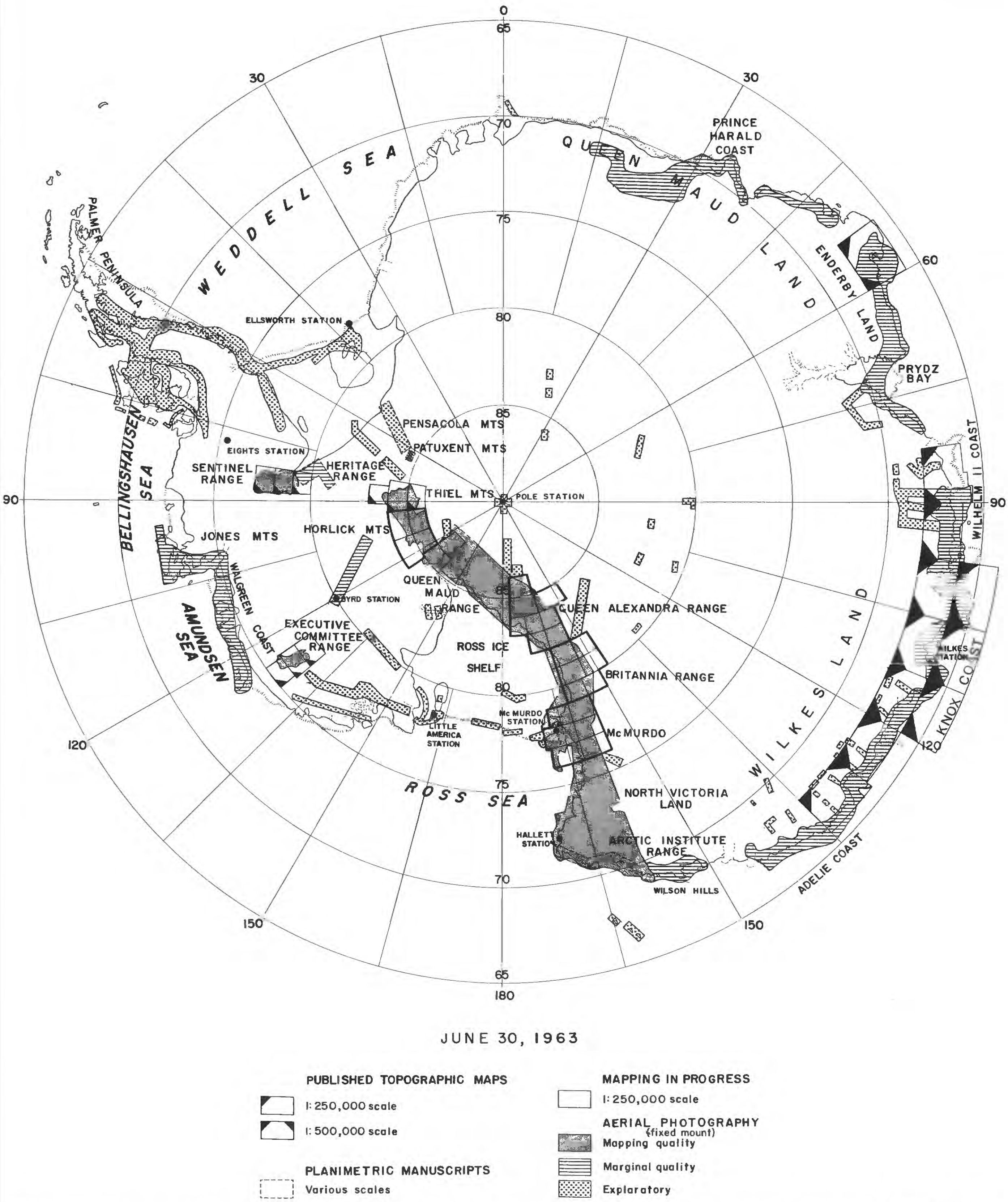


FIGURE 13.—Index map of Antarctica showing status of topographic mapping by the U.S. Geological Survey as of June 30, 1963.

selecting optimum methods for new mapping, for programming research, and for formulating standard procedures.

Major research projects in topographic surveys and mapping require a group effort by engineers and cartographers of different backgrounds and abilities. An example of such a group effort is the experiment, currently underway, in various techniques of mapping planimetry (roads, building, streams, bodies of water, woodland). The objective is to devise new approaches and to evaluate the degree to which such planimetric data, appropriately reproduced, might be used to increase topographic coverage of the unmapped areas of the United States. The systems under consideration are based on readily available materials, data, techniques, and instrumentation.

In one proposed system, aerotriangulation will be accomplished with available Army Map Service 1:60,000-scale photography, using stereotemplet methods and existing horizontal control. A skeletal framework of readily identifiable planimetric features will be compiled by stereoplotter from the same photography. The remaining detailed planimetry will be compiled by monocular methods from recent 1:20,000-scale U.S. Agricultural Stabilization and Conservation Service photographs.

A second project is the investigation of effective means for accurate and economical topographic mapping of areas covered by dense evergreen woods. Field techniques for obtaining detailed ground information include new radar-type sensors as well as panchromatic and infrared photographic coverage.

## FIELD SURVEYS

### Field test of second-order control surveys

In the summer of 1962, six test projects were undertaken in cooperation with the U.S. Coast and Geodetic Survey to determine whether the control surveys executed by the Geological Survey for topographic mapping could be strengthened to meet second-order standards economically through the use of modern equipment.

The tests included 4 projects for horizontal control, and 2 projects involving vertical control. The horizontal control was extended by traverse, using electronic equipment to measure distances and Wild T–2 theodolites to measure angles. The vertical control was extended by conventional second-order methods, using a Staack spirit level in one project and a Zeiss Ni2 automatic level in the other. There were no unusual problems in the fieldwork, and all projects were completed during the summer of 1962. The results of both the horizontal and vertical control were adjusted by the Coast and Geodetic Survey, and accuracies in all the work were well within the second-order requirements.

As a result of these tests, the following agreements were reached by the Geological Survey and the Coast and Geodetic Survey in regard to future control surveys, for mapping by the Geological Survey:

1. Where feasible, horizontal control will be completed by the Coast and Geodetic Survey prior to the beginning of mapping operations by the Geological Survey. Any horizontal control which cannot be completed in time by the Coast and Geodetic Survey will be performed by the Geological Survey to second-order standards. The Coast and Geodetic Survey will be responsible for all final adjustments into the national geodetic network.
2. The basic vertical control required for mapping by the Geological Survey will continue to be done to third-order standards, on the premise that the slight initial difference in elevation accuracy is not worth the considerable difference in cost, and probably would not be discernible after a few years because of earth-crust movements.

### Level-evaluation program

A program started in 1962 to evaluate some of the precise leveling instruments on the market includes both shop inspection and tests, and field tests using the Kissam-Irish precision test, which is designed to evaluate a particular intrument under the existing atmospheric conditions. To date, 5 pendulum-type and 2 spirit-type instruments have been tested. The tests indicated that 4 of the pendulum-type levels and 1 of the spirit-type levels are sufficiently precise for third-order geodetic leveling. Each instrument was tested for precision, for limitations on the permissible length of sight, for necessity of shading the instrument, and for ease of operation.

### Portable surveying towers

Experience with portable surveying towers (described by Buckmaster and others, 2–63) indicates that a most important characteristic is the speed of raising and lowering. To save time, portable towers are transported, raised, and lowered fully assembled on trucks with powered hoists.

Towers about 40 feet high are used more than higher ones, because of their rigidity, short setup time, and ease of highway transportation. However, the truck carriage-hoists have been designed with a capacity to erect a 75-foot tower when greater tower height is essential. Connection joints have been designed so that preassembled sections can be added quickly to extend towers to the required height. The same connectors permit quick removal of the platform unit for long highway trips. Heavier corner tubes and braces may be used should greater stability be desired for more precise surveys.

### Airborne control-survey system

An airborne control-survey system (ABC system) is being tested for extending geodetic control by a combined system of ground-to-air measurements (Buckmaster and others, 1–63). A helicopter serves as an aerial platform above ground points for which geodetic position is desired. When hovering over a desired ground position, the craft serves as a target for angle measurements from one or more ground stations and as the "remote" station for the electronic distance-measuring equipment.

Tests were conducted in July 1962 to determine the degree of horizontal accuracy obtainable with the ABC system. The ABC control net was tied to existing first-order triangulation stations and the two positions were compared. The unadjusted closures gave a maximum error of 2.1 feet, an average error of 1.34 feet, and a probable error of 0.96 foot. In terms of a representative fraction, the closure is about 1 : 100,000, using the most direct route from the base line. Based on the results of these tests, a horizontal accuracy of 2 feet can be expected within the working range of the equipment.

The ABC system was used experimentally on a mapping project in Arizona during January and February 1963. Time, cost, and accuracy of the ABC system were compared with conventional ground-survey methods. One 7½-minute quadrangle previously surveyed by ground parties was resurveyed with the ABC system using the same field crews. Six other 7½-minute quadrangles were surveyed solely by the ABC system. Horizontal and vertical positions were obtained for about 200 points. Vertical control had been predetermined by field methods on 32 of these points. Comparison of the results obtained by the two methods indicated a difference of about 0.6 foot in the vertical data. The horizontal control data have not yet been completely analyzed.

## PHOTOGRAMMETRY

### Diapositive printers

In a continuing study of automatic dodging systems for diapositive printers, a new cone assembly for the 153/55 printer was designed, fabricated, and tested in 1963. Based on the principle of infrared quenching, this printer will automatically dodge diapositives, producing imagery that is easier to interpret in stereocompilation.

In an effort to lessen the effect of distortion inherent in 90° aviogon photography, new corrector plates were supplied for four 153/153 diapositive printers, and corrector plates are being obtained for four 153/55 diapositive printers. In addition, a corrector plate was designed and procured for the 153/55 printer for superwide-angle photography. Included in the design of all new corrector plates is a compensation for earth curvature.

### Diapositive quality control

The Geological Survey and other government agencies, in cooperation with manufacturers, have developed new and more rigid specifications for diapositive plates. A program of quality control has also been started that will detect small differences in emulsion characteristics. With uniform-quality plates assured, the diapositive technician can select the type of emulsion and the procedure that will extract the greatest amount of information from the aerial film.

The need for improved quality in diapositive emulsions has been emphasized by the increased use of orthophotography, and other direct-image mapping techniques, wherein the image quality plays an important role in the appearance of the final map.

### Orthophotography

An experimental map publication, a four-color orthophotomosaic print of the Roanoke SW, Virginia, 7½-minute quadrangle, was completed in 1963. Press plates prepared from photo negatives processed by photo-image enhancement techniques permitted reproduction without half-tone screening. The experimental publication is pleasing in its general appearance and complies with the National Map Accuracy Standards for horizontal position.

Detailed drawings and specifications for a new orthophotoscope, model T–64, have been completed. Investigations are continuing of the feasibility of digitizing the X, Y, and Z data derived during the scanning process. The data may be used subsequently both to control the exposure of orthophotography and to determine elevations for contouring or profiling.

### Modified Kelsh plotter

Shorter-focal-length lenses mounted in Kelsh projectors to produce an optimum projection distance of 550 mm (instead of 760 mm) with a magnification of 3.6 : 1 (instead of 5 : 1) are being investigated. The use of contact-size diapositives at a principal distance of 153 mm is not changed by this modification. Projected model scales are comparable to those projected by the ER–55 plotter for photography at equal flight heights. By the use of a smaller model scale, undesirably large pantograph reductions are avoided. Laboratory tests of the projected model show an increase in illumination and a more even distribution of light compared with that of the standard Kelsh plotter. Operational tests are underway to determine if this modification enhances the efficiency of the instrument for map compilation.

### Analytical aerotriangulation

Development is nearing completion on a fully analytical system of aerotriangulation and the associated computational program for the Burroughs-200 electronic computer. The computer program can produce solutions for blocks of up to 22 photographs in any configuration. The system provides an iterative, least-squares, simultaneous solution for exposure station positions and for the subsequent computation of the geographic positions and elevations of the photogrammetric control points ("pass points") needed for topographic map compilation. The program embodies provisions for correcting the systematic lens-distortion and film-distortion errors and for a least-square adjustment of random errors in the measured photo-coordinates.

### Analytical strip and block adjustment methods

In addition to this fully analytical system, two research projects involve the developing and evaluating of computational methods of adjusting instrumentally bridged strips to one another and to control.

Engineers of the Topographic Division are investigating a system of horizontal adjustment using a method and computer program devised by Schut.[110] They first formulated and tested a modified version of Schut's method, and found that the modified method produced acceptable results for short strips (7 or 8 models) bridged with either the Wild A-7 plotter or with ER-55 equipment. For longer strips, particularly those bridged with ER-55 equipment, the more accurate full solution is needed. The objectives of the project are to evaluate the full solution when used with 16 model strips bridged with the A-7 plotter, and to explore the merits of a proposed method of forming the strips analytically from two-model strip sections.

Also in progress is a study aimed at appraising an analytical method for the vertical adjustment of instrumentally bridged strips. Basically, the method involves the generation of a vertical-error surface for each strip, based upon a polynomial of the second degree, and an iterative adjustment of the strips to the control and to the adjoining strips through adjustment of the error surfaces. If it proves to have sufficient accuracy, the method holds promise of reducing costs because it would require fewer field-survey elevations and would permit greater latitude in their location.

[110] Schut, G. H., 1961, A method of block adjustment of horizontal coordinates: Canadian Surveyor, v. 15, no. 7, pp. 376-385.

### Super-wide-angle photogrammetric system

In continuing investigations of super-wide-angle photogrammetric systems in mapping, flight testing of the Wild RC-9 aerial camera, which has an angular coverage of 120°, has been successfully completed. Photography was obtained over Los Angeles, Calif., where the wealth of planimetric details and abundant ground control will permit evaluation of the resolution and flatness of stereomodels projected from super-wide-angle photography. A pair of Balplex super-wide-angle projectors and a Wild B-8 stereoplotter will be used for further operational testing.

## PROGRAM MANAGEMENT

### Computer-plotted index maps

An electronic method for printing map-index data, called TAG (Tabulation And Graphic) has been developed. Positions of selected quadrangle maps are plotted by the Burroughs-220 electronic computer to fit a rectangular projection at a scale of about 1:4,400,000. Maps can be prepared to show, by symbols, a variety of information, such as the status of individual quadrangles, from data coded in an electronic computer. A corresponding tabular listing of the information can be produced simultaneously. A map of the United States requires 5 strips which can be prepared with 4 carbon copies in about 30 minutes.

## NATIONAL ATLAS

Plans for the scope, content, and organization of the National Atlas of the United States have been completed and blue-line plotting bases have been made at scales of 1:7,500,000, 1:17,000,000 and 1:34,000,000. The project has been directed by Arch C. Gerlach, who is on loan from the Library of Congress. Work was started in 1962, in response to a recommendation from the National Academy of Sciences, but was suspended at the beginning of fiscal 1964.

The National Atlas is intended to be a reference and research tool for Government agencies, educational institutions, large libraries, executives in business and industry, and individual scholars. There will be a small group of general reference maps at the front, but the principal body of 350 pages of maps will be special-subject maps dealing with the mappable characteristics of this country. These will include physical features such as landforms, geology, soils, vegetation, and climate; historical events such as discovery, exploration, battlefields, land grants, and territorial growth; economic activities such as agriculture, industry, resources, transportation, and taxation; social conditions such as population distribution and structure, educational achievement, cultural and research centers; administrative subdivisions of the United States; index maps of cartographic and aerial-photo coverage for various purposes and for different scales; and world maps showing foreign trade, aid programs, student exchanges, defense organizations, and other aspects of the United States' activity in world affairs. Plans have been completed for indexing the atlas by means of computer and automatic printing equipment.

## HOW TO OBTAIN GEOLOGICAL SURVEY PUBLICATIONS

All book publications, maps, and charts published by the Survey are listed in "Publications of the Geological Survey through 1961" (in press), and in supplements, which keep the list up to date. New releases are announced each month in "New Publications of the Geological Survey". All of these lists of publications are free upon request to the GEOLOGICAL SURVEY, WASHINGTON, D.C., 20242. They may be consulted at many public and educational-institution libraries, and at the Geological Survey offices named below.

Books, maps, charts, and folios that are out of print can no longer be purchased from any official source. They may be consulted at many libraries, and some can be purchased from dealers in second-hand books.

### Ordering book reports

Professional papers, bulletins, water-supply papers and miscellaneous book publications can be purchased from the SUPERINTENDENT OF DOCUMENTS, GOVERNMENT PRINTING OFFICE, WASHINGTON, D.C., 20402. Prepayment is required and may be made by money order or check payable to that office, or in cash—exact amount—at sender's risk. Postage stamps are not accepted. Book publications also may be purchased on an over-the-counter basis from the following Geological Survey offices: 468 NEW CUSTOMHOUSE, DENVER, COLO.; 437 FEDERAL BUILDING, SALT LAKE CITY, UTAH; 602 THOMAS BUILDING, DALLAS, TEX.; 1031 BARTLETT BUILDING, LOS ANGELES, CALIF.; 232 APPRAISERS BUILDING, SAN FRANCISCO, CALIF.; SOUTH 157 HOWARD ST., SPOKANE, WASH.; and 503 CORDOVA BUILDING, ANCHORAGE, ALASKA.

Circulars may be obtained free on application to the GEOLOGICAL SURVEY, WASHINGTON, D.C., 20242.

### Ordering maps and charts

Maps, charts, folios, and hydrologic atlases are sold by the Geological Survey. Mail orders for those covering areas east of the Mississippi River should be addressed to the GEOLOGICAL SURVEY, WASHINGTON, D.C., 20242, and for areas west of the Mississippi River to the GEOLOGICAL SURVEY, FEDERAL CENTER, DENVER, COLO., 80225. Remittances should be sent by check or money order made payable to the Geological Survey or in cash—exact amount—at the sender's risk. Postage stamps are not accepted. Retail prices are quoted in lists of publications and, for topographic maps, in indexes to topographic mapping for individual states. On an order amounting to $10 or more at the retail price, 20 percent discount is allowed; on orders of $60 or more, 40 percent discount is allowed. These publications also may be obtained on an area basis, by over-the-counter sale (but not by mail) from the other Geological Survey offices mentioned above. Residents of Alaska may order Alaska maps from the GEOLOGICAL SURVEY, 310 FIRST AVE., FAIRBANKS, ALASKA, 99701. Most geologic maps are available flat, or folded in envelopes.

Indexes to topographic-map coverage of the various States are released periodically and are free on application. The release of revised indexes is announced in the monthly list of new publications of the Geological Survey. Each State index shows the areas mapped and gives lists of Geological Survey offices from which maps may be purchased and of local agents who sell the maps.

Advance material available from current topographic mapping is indicated on quarterly releases of State index maps. This material, including such items as aerial photography, geodetic-control data, and preliminary maps in various stages of preparation and editing, is available for purchase. Information concerning the ordering of these items is given on each State index. Requests for indexes or inquiries concerning availability of advance materials should be directed to the MAP INFORMATION OFFICE, U.S. GEOLOGICAL SURVEY, WASHINGTON, D.C., 20242.

### State water-resources investigations folders

A series of 8- by 10½-inch folders entitled "Water Resources Investigations in [State]" is a new project of the Water Resources Division to inform the public about its current program in the 50 States and Puerto Rico, (p. A21). As the State programs change, the folders will be revised. Folders for all 50 States are available free on request to the U.S. Geological Survey.

### Open-file reports

Open-file reports include unpublished manuscript reports, maps, and other material made available for public consultation and use. Arrangements can generally be made to reproduce them at private expense. The date and places of availability for consultation by the public are given in press releases or other forms of public announcement. In general, open-file reports are placed in one or more of the three Geological Survey libraries: ROOM 1033, GENERAL SERVICES BLDG., WASHINGTON, D.C.; BLDG. 25, FEDERAL CENTER, DENVER, COLO.; and 345 MIDDLEFIELD ROAD, MENLO PARK, CALIF. Other depositories may include one or more of the Geological Survey offices listed on pages A252 to A258, or interested State agencies. Many open-file reports are replaced later by formally printed publications.

# PUBLICATIONS IN FISCAL YEAR 1963

Listed below are the contents of already-published Chapters B and C of Geological Survey Research 1963, comprising Articles 1–121, many of which are referred to in the preceding pages. Chapter D will complete the volume. These contents are followed on page A203 by a complete list of citations of abstracts, papers, reports, and maps of Geological Survey authors published or otherwise released to the public during fiscal year 1963. The list includes articles in Geological Survey Research 1962 published after July 1, 1962, in Professional Papers 450–C, –D, and –E. Publications are listed alphabetically by senior author; each citation is identified by a number, for example, 1–63, which indicates the first entry for that author for the calendar year 1963. The number is followed by the names of coauthors and the citation. References in the preceding text are listed by author and serial number—for example, Smith (1–63).

## SHORT PAPERS IN GEOLOGY AND HYDROLOGY

### *PROFESSIONAL PAPER 475–B*






708-043 O-63-14

## PROFESSIONAL PAPER 475–C

# LIST OF PUBLICATIONS

ADAMS, John Kendal
- 1-62. (and BOGGESS, D. H.) Water-table, surface-drainage, and engineering soils map of the Taylors Bridge area, Delaware: U. S. Geol. Survey open-file report, 1962.
- 2-62. (and BOGGESS, D. H.) Water-table, surface-drainage, and engineering soils map of the Wilmington area, Delaware: U. S. Geol. Survey open-file report, 1962.
- 3-62. (and BOGGESS, D. H., and COSKERY, O. J.) Water-table, surface-drainage, and engineering soils map of the Clayton area, Delaware: U. S. Geol. Survey open-file report, 1962.
- 1-63. (and BOGGESS, D. H.) Water-table, surface-drainage, and engineering soils map of the Ellendale area, Delaware: U. S. Geol. Survey open-file report, 1963.
- 2-63. (and BOGGESS, D. H.) Water-table, surface-drainage, and engineering soils map of the Hickman area, Delaware: U. S. Geol. Survey open-file report, 1963.
- 3-63. (and BOGGESS, D. H., and DAVIS, C. F.) Water-table, surface-drainage, and engineering soils map of the Lewes area, Delaware: U. S. Geol. Survey open-file report, 1963.
- 4-63. (and BOGGESS, D. H.) Water-table, surface-drainage, and engineering soils map of the Harbeson area, Delaware: U. S. Geol. Survey open-file report, 1963.
- 5-63. (and BOGGESS, D. H., and Coskery, O. J.) Water-table, surface-drainage, and engineering soils map of the Seaford East area, Delaware: U. S. Geol. Survey open-file report, 1963.

ADAMS, John Wagstaff
- 1-62. (and HILDEBRAND, F. A., and HAVENS, R. G.) Thalenite from Teller County, Colorado: Art. 121 in U. S. Geol. Survey Prof. Paper 450-D, p. D6-D8, 1962.

ADDICOTT, Warren Oliver
- 1-63. An unusual occurrence of Tresus nuttalli (Conrad)(Pelecypoda): Veliger, v. 5, no. 4, p. 143-145, 1963.
- 2-63. Interpretation of the invertebrate fauna from the upper Pleistocene Battery Formation near Crescent City, California: California Acad. Sci. Proc., 4th ser., v. 31, no. 13, p. 341-347, 1963.

ADKISON, Windsor Lester
- 1-63. (and JOHNSTON, J. E.) Geology and coal resources of the Salyersville North quadrangle, Magoffin, Morgan, and Johnson Counties, Kentucky: U. S. Geol. Survey Bull. 1047-B, p. 25-55, 1963.
- 2-63. Subsurface geologic cross section of Paleozoic rocks from Butler County to Stafford County, Kansas: Kansas Geol. Survey Oil and Gas Inv. 28, 90 p., 1963. (Prepared cooperatively with U. S. Geological Survey.)

ADLER, Isidore
- 1-62. (and DWORNIK, E. J., and ROSE, H. J., Jr.) The detection of sulphur in contamination spots in electron probe X-ray microanalysis: British Jour. Appl. Physics (London), v. 13, no. 5, p. 245-246, 1962.
- 1-63. The electron probe: Internat. Sci. and Technology, no. 17, p. 39-45, 1963.
- 2-63. Cosmic particle study, in Astrogeologic studies--Annual progress report, Aug. 25, 1961 to Aug. 24, 1962, Pt. C, Cosmochemistry and petrography: U. S. Geol. Survey open-file report, p. 163-168, 1963.

ADOLPHSON, Donald G.
- 1-62. Artesian water from glacial drift near Lehr, Logan and McIntosh Counties, North Dakota: North Dakota State Water Conserv. Comm., North Dakota Ground-Water Study 38, 22 p., 1962. (Prepared by U. S. Geological Survey in coop. with North Dakota State Water Conservation Commission and North Dakota Geological Survey.)

AKERS, Jay P.
- 1-61. The Chinle Formation of the Paria Plateau area, Arizona and Utah [abs.]: Arizona Geol. Soc. Digest, v. 4, p. 175, 1961.
- 1-62. (and IRWIN, J. K., and STEVENS, P. R., and McCLYMONDS, N. E.) Geology of the Cameron quadrangle, Arizona: U. S. Geol. Survey Geol. Quad. Map GQ-162, 1962.

ALBEE, Arden Leroy
- 1-62. Relationships between the mineral association, chemical composition and physical properties of the chlorite series: Am. Mineralogist, v. 47, nos. 7-8, p. 851-870, 1962.

ALBERS, John P.
- 1-62. (and STEWART, J. H.) Precambrian(?) and Cambrian stratigraphy in Esmeralda County, Nevada: Art. 126 in U. S. Geol. Survey Prof. Paper 450-D, p. D24-D27, 1962.

ALBIN, Donald R.
- 1-60. Murfreesboro area: Arkansas Geol. and Conserv. Comm. Spec. Ground-Water Rept. 1, 22 p. (Prepared in coop. with U. S. Geol. Survey.)
- 1-62. Résumé of the ground-water resources of Bradley, Calhoun, and Ouachita Counties, Arkansas: U. S. Geol. Survey open-file report, 9 p., 1962.
- 1-63. Geology and ground-water resources of Bradley, Calhoun, and Ouachita Counties, Arkansas: U. S. Geol. Survey open-file report, 66 p., 1963.
- 2-63. Well records, depth-to-water measurements and logs of selected wells and test holes, and chemical analyses of ground water in Bradley, Calhoun, and Ouachita Counties, Arkansas: U. S. Geol. Survey open-file report, 159 p., 1963.

ALLEN, William Burrows
- 1-62. (and HAHN, G. W., and TUTTLE, C. R.) Geohydrological data for the upper Pawcatuck River basin, Rhode Island: U. S. Geol. Survey open-file report, 123 p., 1962.

ALLINGHAM, John Wing
- 1-62. (and ZIETZ, Isidore) Geophysical data on the Climax stock, Nevada Test Site, Nye County, Nevada: Geophysics, v. 27, no. 5, p. 599-610, 1962.

ALTSCHULER, Zalman Samuel
- 1-63. (and DWORNIK, E. J., and KRAMER, Henry) Weathering of montmorillonite to kaolinite in Florida [abs.]: Geol. Soc. America Spec. Paper 73, p. 103, 1963.

ALVORD, Donald C.
- 1-62. (and TRENT, V. A.) Geology of the Williamson quadrangle in Kentucky: U. S. Geol. Survey Geol. Quad. Map GQ-187, 1962. (Prepared in coop. with Kentucky Geological Survey.)

ANDERS, Robert Bernard
- 1-62. (and NAFTEL, W. L.) Pumpage of ground water and changes in water levels in Galveston County, Texas, 1958-62: U. S. Geol. Survey open-file report, 32 p., 1962.
- 2-62. Ground-water geology of Karnes County, Texas: U. S. Geol. Survey Water-Supply Paper 1539-G, p. G1-G40, 1962 [1963].
- 1-63. (and NAFTEL, W. L.) Pumpage of ground water and changes in water levels in Galveston County, Texas, 1958-62: Texas Water Comm. Bull. 6303, 33 p., 1963. (Prepared by U. S. Geological Survey in coop. with Texas Water Commission and City of Galveston.)

ANDERSON, Charles Alfred
- 1-62. Projects and publications of the Geologic Division, U. S. Geological Survey, in Geological investigations in Georgia, 1962: Georgia Mineral Newsletter, v. 15, nos. 3-4, p. 40-41, 1962.
- 2-62. (and BLACET, P. M.) Preliminary geologic map of the NE¼ Mount Union quadrangle, Yavapai County, Arizona: U. S. Geol. Survey open-file report, 1962.

ANDERSON, Lennart A.
- 1-62. (and PETRAFESO, F. A.) Aeromagnetic map of parts of Clay, Wilkin, and Otter Tail Counties, Minnesota: U. S. Geol. Survey Geophys. Inv. Map GP-327, 1962 [1963].
- 2-62. (and ZANDLE, G. L., and others) Aeromagnetic map of Norman and part of Mahnomen Counties, Minnesota: U. S. Geol. Survey Geophys. Inv. Map GP-325, 1962.
- 1-63. (and BROMERY, R. W., and TYSON, N. S.) Aeromagnetic map of the Spider Lake quadrangle and part of Musquacook Lakes quadrangle, Piscataquis and Aroostook Counties, Maine: U. S. Geol. Survey Geophys. Inv. Map GP-376, 1963.
- 2-63. (and HAWKINS, D. R., and others) Aeromagnetic map of parts of Wilkin, Otter Tail, Grant, and Traverse Counties, Minnesota: U. S. Geol. Survey Geophys. Inv. Map GP-328, 1963.
- 3-63. (and NATOF, N. W. C., and others) Aeromagnetic map of part of the Fish River Lake quadrangle, Aroostook County, Maine: U. S. Geol. Survey Geophys. Inv. Map GP-371, 1963.
- 4-63. (and NATOF, N. W. C., and others) Aeromagnetic map of part of the Mooseleuk Lake quadrangle, Aroostook and Piscataquis Counties, Maine: U. S. Geol. Survey Geophys. Inv. Map GP-373, 1963.
- 5-63. (and BROMERY, R. W., and McGOWAN, E. F.) Aeromagnetic map of the Millinocket Lake quadrangle, Aroostook, Piscataquis, and Penobscot Counties, Maine: U. S. Geol. Survey Geophys. Inv. Map GP-377, 1963.
- 6-63. (and NATOF, N. W. C., and others) Aeromagnetic map of part of the Greenlaw quadrangle, Aroostook County, Maine: U. S. Geol. Survey Geophys. Inv. Map GP-374, 1963.
- 7-63. (and NATOF, N. W. C., and others) Aeromagnetic map of part of the Winterville quadrangle, Aroostook County, Maine: U. S. Geol. Survey Geophys. Inv. Map GP-372, 1963.
- 8-63. (and TYSON, N. S., and others) Aeromagnetic map of the northwestern part of Cook County, Minnesota: U. S. Geol. Survey Geophys. Inv. Map GP-361, 1963.
- 9-63. (and ZANDLE, G. L., and others) Aeromagnetic map of parts of Clay and Becker Counties, Minnesota: U. S. Geol. Survey Geophys. Inv. Map GP-326, 1963.

ANDERSON, Roy Ernest
- 1-63. Pyroclastic flows of the Missouri Precambrian [abs.]: Geol. Soc. America Spec. Paper 73, p. 105, 1963.

ANDREASEN, Gordon Ellsworth
- 1-62. (and SMITH, F. C., and others) Aeromagnetic map of part of the Cornwall quadrangle, Orange County, New York: U. S. Geol. Survey Geophys. Inv. Map GP-337, 1962.
- 2-62. (and SMITH, F. C., and others) Aeromagnetic map of the Popolopen Lake quadrangle, Orange and Rockland Counties, New York: U. S. Geol. Survey Geophys. Inv. Map GP-340, 1962.
- 3-62. (and SMITH, F. C., and others) Aeromagnetic map of the West Point quadrangle, Orange, Dutchess, and Putnam Counties, New York: U. S. Geol. Survey Geophys. Inv. Map GP-338, 1962.
- 4-62. (and VARGO, J. L., and others) Aeromagnetic map of part of the Haverstraw quadrangle, Rockland and Westchester Counties, New York: U. S. Geol. Survey Geophys. Inv. Map GP-343, 1962.
- 5-62. (and VARGO, J. L., and others) Aeromagnetic map of the Peekskill quadrangle, Rockland, Orange, Putnam, and Westchester Counties, New York: U.,S. Geol. Survey Geophys. Inv. Map GP-341, 1962.
- 6-62. (and VARGO, J. L., and others) Aeromagnetic map of the Thiells quadrangle, Rockland and Orange Counties, New York: U. S. Geol. Survey Geophys. Inv. Map GP-342, 1962.
- 7-62. (and ZIETZ, Isidore) Limiting parameters in the magnetic interpretation of a geologic structure: Geophysics, v. 27, no. 6, pt. 1, p. 807-814, 1962.
- 1-63. (and CHANDLER, E. J., and others) Aeromagnetic map of the High Bridge quadrangle, Warren and Hunterdon Counties, New Jersey: U. S. Geol. Survey Geophys. Inv. Map GP-349, 1963.
- 2-63. (and HENDERSON, J. R., and CHANDLER, E. J., and others) Aeromagnetic map of parts of the Tranquility and Stanhope quadrangles, Warren, Sussex, and Morris Counties, New Jersey: U. S. Geol. Survey Geophys. Inv. Map GP-346, 1963.
- 3-63. (and HENDERSON, J. R., and CHANDLER, E. J., and others) Aeromagnetic map of the Califon quadrangle and part of the Gladstone quadrangle, Hunterdon and Morris Counties, New Jersey: U. S. Geol. Survey Geophys. Inv. Map GP-350, 1963.

ANDREASEN, Gordon Ellsworth--Continued
4-63. (and HENDERSON, J. R., and CHANDLER, E. J., and others) Aeromagnetic map of the Hackettstown quadrangle and part of the Chester quadrangle, Hunterdon, Morris, and Warren Counties, New Jersey: U. S. Geol. Survey Geophys. Inv. Map GP-348,, 1963.
5-63. (and CHANDLER, E. J., and others) Aeromagnetic map of the Washington quadrangle and part of the Blairstown quadrangle, Warren, Hunterdon, and Morris Counties, New Jersey: U. S. Geol. Survey Geophys. Inv. Map GP-347, 1963.
6-63. (and DEMPSEY, W. J., and VARGO, J. L., and others) Aeromagnetic map of part of the Naknek quadrangle, Alaska: U. S. Geol. Survey Geophys. Inv. Map GP-353, 1963.
7-63. Aeromagnetic map of parts of the Ugashik and Karluk quadrangles, Alaska: U. S. Geol. Survey Geophys. Inv. Map GP-354, 1963.
8-63. (and PETRAFESO, F. A.) Aeromagnetic map of the east-central part of the Death Valley National Monument, Inyo County, California: U. S. Geol. Survey Geophys. Inv. Map GP-428, 1963.

APPLEMAN, Daniel Everett
1-63. X-ray crystallography of wegscheiderite ($Na_2CO_3 \cdot 3NaHCO_3$): Am. Mineralogist, v. 48, nos. 3-4, p. 404-410, 1963.

ARMSTRONG, Frank Clarkson
1-63. Indirect dating of the Paris thrust fault, southeastern Idaho [abs.]: Geol. Soc. America Spec. Paper 73, p. 21, 1963.
2-63. (and CRESSMAN, E. R.) The Bannock thrust zone, southeastern Idaho: U. S. Geol. Survey Prof. Paper 374-J, p. J1-J22, 1963.

ARNDT, Harold Harry
1-62. (and WOOD, G. H., Jr., and TREXLER, J. P.) Subdivision of the Catskill Formation in the western part of the Anthracite region of Pennsylvania: Art. 72 in U. S. Geol. Survey Prof. Paper 450-C, p. C32-C36, 1962.
1-63. (and DANILCHIK, Walter, and WOOD, G. H., Jr.) Geology of anthracite in the western part of the Shamokin quadrangle, Northumberland County, Pennsylvania: U. S. Geol. Survey Coal Inv. Map C-47, 2 sheets, 1963.
2-63. (and WOOD, G. H., Jr., and DANILCHIK, Walter) Geology of anthracite in the southern part of the Trevorton quadrangle, Northumberland County, Pennsylvania: U. S. Geol. Survey Coal Inv. Map C-48, 2 sheets, 1963.

ARNOLD, Ralph Gunther
1-62. (and COLEMAN, R. G., and FRYKLUND, V. C., Jr.) Temperature of crystallization of pyrrhotite and sphalerite from the Highland-Surprise mine, Coeur d'Alene district, Idaho: Econ. Geology, v. 57, no. 8, p. 1163-1174, 1962.

ASH, Sidney R.
1-62. The conodonts--A neglected stratigraphic tool in New Mexico [abs.], in New Mexico Geol. Soc., Mogollon Rim region, east-central Arizona, 13th Field Conf., Oct. 1962, Guidebook, p. 173, 1962.

AULT, Wayne Urban
1-62. (and RICHTER, D. H., and STEWART, D. B.) A temperature measurement probe into the melt of the Kilauea Iki lava lake in Hawaii: Jour. Geophys. Research, v. 67, no. 7, p. 2809-2812, 1962; abs., no. 9, p. 3539, 1962.

BACHMAN, George Odell
1-62. (and DANE, C. H.) Preliminary geologic map of the northeastern part of New Mexico: U. S. Geol. Survey Misc. Geol. Inv. Map I-358, 1962.
1-63. (and MYERS, D. A.) Geology of the Bear Peak NE quadrangle, Dona Ana County, New Mexico: U. S. Geol. Survey Misc. Geol. Inv. Map I-374, 1963.

BACK, William
1-63. Calcium carbonate saturation of ground water in Central Florida [abs.]: Geol. Soc. America Spec. Paper 73, p. 106-107, 1963; Ground Water, Jour. Natl. Water Well Assoc., v. 1, no. 2, p. 40, 1963.

BADER, John S.
1-63. Effect of faulting in alluvium on the occurrence, movement, and quality of ground water in the Twentynine Palms area, California [abs.]: Geol. Soc. America Spec. Paper 73, p. 22, 1963.

BAGNOLD, Ralph A.
1-62. Auto-suspension of transported sediment--Turbidity currents: Royal Soc. Proc. (London), Ser. A, v. 265, no. 1322, p. 315-319, 1962.

BAIN, George L.
1-63. Stratigraphy and structure in the Durham area, North Carolina [abs.]: Geol. Soc. America, Southeastern Sec., Ann. Mtg., Roanoke, Virginia, Apr. 1963, Program, p. 16-17, 1963.

BAKER, Arthur Alan
1-63. Geology of Spanish Fork Canyon [Utah] [abs.]: Geol. Soc. America Spec. Paper 73, p. 76, 1963.

BAKER, Ernest T., Jr.
1-62. (and LONG, A. T., Jr., and REEVES, R. D., and WOOD, L. A.) A reconnaissance of the ground-water resources of the Red River, Sulphur River, and Cypress Creek basins, Texas: U. S. Geol. Survey open-file report, 215 p., 1962.
1-63. Ground-water geology of Grayson County, Texas: U. S. Geol. Survey Water-Supply Paper 1646, 61 p., 1963.

BAKER, John H.
1-62. (and WAHLBERG, J. S.) Effect of sodium and calcium on strontium adsorption by albite, kaolinite, and montmorillonite [abs.]: Jour. Geophys. Research, v. 67, no. 9, p. 3540, 1962.

BAKER, Roger Crane
1-62. A reconnaissance of the ground-water resources of the lower Rio Grande basin, Texas: U. S. Geol. Survey open-file report, 47 p., 1962.
2-62. (and HUGHES, L. S., and YOST, I. D.) Natural sources of salinity in the Brazos River, Texas, with particular reference to the Croton and Salt Croton Creek basins: U. S. Geol. Survey open-file report, 133 p., 1962.

BALLANCE, Wilbur C.
1-62. Ground-water levels in New Mexico, 1961--Basic data report: Santa Fe, New Mexico State Engineer, 130 p., 1962. (Prepared in coop. with U. S. Geological Survey.)
2-62. (and HOOD, J. W., and HUDSON, J. D., and COX, E. R., and MOURANT, W. A., and BUSCH, F. E., and DOTY, G. C.) Ground-water levels in New Mexico, 1960, with a section on Pecos Valley Artesian Conservancy District recorder wells, by R. L. Borton: New Mexico State Engineer Tech. Rept. 27, 215 p., 1962. (Prepared in coop. with U. S. Geological Survey.)

BALSLEY, James Robinson, Jr.
1-62. (and MEUSCHKE, J. L., and BLANCHETT, Jean) Aeromagnetic map of the Eagle Harbor quadrangle, Keweenaw County, Michigan: U. S. Geol. Survey Geophys. Inv. Map GP-314, 1962.
1-63. (and MEUSCHKE, J. L., and BLANCHETT, Jean) Aeromagnetic map of the Chassell quadrangle, Houghton County, Michigan: U. S. Geol. Survey Geophys. Inv. Map GP-324, 1963.
2-63. (and MEUSCHKE, J. L., and BLANCHETT, Jean) Aeromagnetic map of the Hancock quadrangle, Houghton County, Michigan: U. S. Geol. Survey Geophys. Inv. Map GP-321, 1963.
3-63. (and MEUSCHKE, J. L., and BLANCHETT, Jean) Aeromagnetic map of the Laurium quadrangle, Houghton County, Michigan: U. S. Geol. Survey Geophys. Inv. Map GP-322, 1963.
4-63. (and MEUSCHKE, J. L., and BLANCHETT, Jean) Aeromagnetic map of the South Range quadrangle, Houghton County, Michigan: U. S. Geol. Survey Geophys. Inv. Map GP-323, 1963.
5-63. (and MEUSCHKE, J. L., and BLANCHETT, Jean) Aeromagnetic map of the Bruneau Creek quadrangle, Keweenaw County, Michigan: U. S. Geol. Survey Geophys. Inv. Map GP-320, 1963.
6-63. (and MEUSCHKE, J. L., and BLANCHETT, Jean) Aeromagnetic map of the Phoenix quadrangle, Keweenaw County, Michigan: U. S. Geol. Survey Geophys. Inv. Map GP-313, 1963.
7-63. (and JOESTING, H. R.) Aeromagnetic map of part of the Gulf of Mexico across the Continental Shelf: U. S. Geol. Survey open-file report, 1963.
8-63. (and MEUSCHKE, J. L., and BLANCHETT, Jean) Aeromagnetic map of the Ahmeek quadrangle, Keweenaw and Houghton Counties, Michigan: U. S. Geol. Survey Geophys. Inv. Map GP-318, 1963.
9-3. (and MEUSCHKE, J. L., and BLANCHETT, Jean) Aeromagnetic map of the Delaware quadrangle, Keweenaw County, Michigan: U. S. Geol. Survey Geophys. Inv. Map GP-315, 1963.
10-63. (and MEUSCHKE, J. L., and BLANCHETT, Jean) Aeromagnetic map of the Fort Wilkins quadrangle, Keweenaw County, Michigan: U. S. Geol. Survey Geophys. Inv. Map GP-317, 1963.
11-63. (and MEUSCHKE, J. L., and BLANCHETT, Jean) Aeromagnetic map of the Lake Medora quadrangle, Keweenaw County, Michigan: U. S. Geol. Survey Geophys. Inv. Map GP-316, 1963.
12-63. (and MEUSCHKE, J. L., and BLANCHETT, Jean) Aeromagnetic map of the Mohawk quadrangle, Keweenaw and Houghton Counties, Michigan: U. S. Geol. Survey Geophys. Inv. Map GP-319, 1963.

BALTZ, Elmer Harold, Jr.
1-62. (and WEST, S. W.) Geology and ground-water resources of the southern part of the Jicarilla Apache Indian Reservation and adjacent region to the south and east, New Mexico: U. S. Geol. Survey open-file report, 296 p., 1962.
2-62. (and WEST, S. W., and ASH, S. R.) Potential yield of deep water wells in the southern part of the Jicarilla Apache Indian Reservation and vicinity, San Juan Basin, New Mexico: Art. 171 in U. S. Geol. Survey Prof. Paper 450-D, p. D173-D175, 1962.
1-63. Stratigraphy and geologic structure of uppermost Cretaceous and Tertiary rocks of the east-central part of the San Juan Basin, New Mexico [abs.]: Dissert. Abs., v. 23, no. 7, p. 2489-2490, 1963.
2-63. (and ABRAHAMS, J. H., Jr., and PURTYMAN, W. D.) Preliminary report on the geology and hydrology of Mortandad Canyon near Los Alamos, New Mexico, with reference to disposal of liquid low-level radioactive waste: U. S. Geol. Survey open-file report, 105 p., 1963.

BANNERMAN, Harold MacColl
1-62. Preliminary geologic map of strip along the Oswegatchie River from Little Bow to Richville, Townships of Gouverneur and DeKalb, St. Lawrence County, New York: U. S. Geol. Survey open-file report, 1962.

BARKER, Franklin Brett
1-63. (and ROBINSON, B. P.) Determination of beta activity in water: U. S. Geol. Survey Water-Supply Paper 1696-A, p. A1-A32, 1963.

BARKER, Fred
1-62. Cordierite-garnet gneiss and associated microcline-rich pegmatite at Sturbridge, Massachusetts and Union, Connecticut: Am. Mineralogist, v. 47, nos. 7-8, p. 907-918, 1962.

BARNES, David Fitz
1-61. (and ALLEN, R. V., and BENNETT, H. F.) Preliminary results of gravity surveys in interior Alaska [abs.]: Alaska Oil and Gas Yearbook 1960, p. 86, 1961.

BARNES, Farrell Francis
1-62. Variation in rank of Tertiary coals in the Cook Inlet basin, Alaska: Art. 65 in U. S. Geol. Survey Prof. Paper 450-C, p. C14-C16, 1962.

BARNES, Harley
1-62. (and CHRISTIANSEN, R. L., and BYERS, F. M., Jr.) Cambrian Carrara Formation, Bonanza King Formation, and Dunderberg Shale east of Yucca Flat, Nye County, Nevada: Art 127 in U. S. Geol. Survey Prof. Paper 450-D, p. D27-D31, 1962.

BARNES, Ivan
1-62. Geochemistry of Birch Creek, California [abs.]: Jour. Geophys. Research, v. 67, no. 9, p. 3540, 1962.

BARNES, Ivan--Continued
1-63. Field measurement of alkalinity and pH: U. S. Geol. Survey open-file report, 33 p., 1963.
BARNETT, Ray Hosmer
1-63. (and LASSITER, S. P.) Instrumentation for solid state studies, in Astrogeologic studies--Annual progress report, Aug. 25, 1961 to Aug. 24, 1962, Pt. B, Crater investigations: U. S. Geol. Survey open-file report, p. 127-129, 1963.
BARRACLOUGH, Jack T.
1-62. Ground-water records of Seminole County, Florida: Florida Geol. Survey Inf. Circ. 34, 148 p.,1961 [1962]. (Prepared by U. S. Geological Survey in coop. with Florida Geological Survey, Board of County Commissioners of Seminole County, and City of Sanford.)
2-62. (and MARSH, O. T.) Aquifers and quality of ground water along the gulf coast of western Florida: Florida Geol. Survey Rept. Inv. 29, 28 p., 1962. (Prepared by U. S. Geological Survey in coop. with Florida Geological Survey, Escambia County, Santa Rosa County, and the City of Pensacola.)
BATEMAN, Paul Charles
1-62. Roadsides, in Deepest Valley--Guide to Owens Valley and its mountain lakes, roadsides and trails: San Francisco, California, Sierra Club, p.,15-67, 1962.
2-62. Geology, in Deepest Valley--Guide to Owens Valley and its mountain lakes, roadsides and trails: San Francisco, California, Sierra Club, p. 100-122, 1962.
BATES, Charles Carpenter
1-63. (and PAKISER, L. C., Jr.) Vela Uniform as of early 1963 [abs.]: Am. Assoc. Petroleum Geologists Bull., v. 47, no. 2, p. 350, 1963.
BATES, Robert Glenn
1-62. Aeroradioactivity survey and areal geology of the Oak Ridge National Laboratory area, Tennessee and Kentucky (ARMS-I): U. S. Atomic Energy Comm. Rept. CEX-59.4.15, 42 p., 1962. (Report prepared for U. S. Atomic Energy Commission, Civil Effects Test Operations series, by U. S. Geological Survey.)
BATH, Gordon D.
1-62. Magnetic anomalies and magnetizations of the Biwabik iron-formation, Mesabi area, Minnesota: Geophysics, v. 27, no. 5, p. 627-650, 1962.
2-62. (and JAHREN, C. E., and SCHWARTZ, G. M.) Magnetic susceptibility and magnetizations of the Biwabik iron-formation, Mesabi district, Minnesota [abs.]: Soc. Explor. Geophysicists Yearbook 1962, p. 264-265, 1962.
BAYLEY, Richard William
1-63. A preliminary report on the Precambrian iron deposits near Atlantic City, Wyoming: U. S. Geol. Survey Bull. 1142-C, p. C1-C23, 1963.
BAYNE, Charles K.
1-62. Geology and ground-water resources of Cowley County, Kansas: Kansas State Geol. Survey Bull. 158, 219 p., 1962. (Prepared by U. S. Geological Survey and Kansas State Geological Survey, in coop. with Div. Sanitation of Kansas State Board Health, and Div. Water Resources of Kansas State Board Agriculture.)
BECRAFT, George Earle
1-63. (and WEIS, P. L.) Geology and mineral deposits of the Turtle Lake quadrangle, Washington: U. S. Geol. Survey Bull. 1131, 73 p., 1963.
BEDINGER, Marion S.
1-61. (and REED, J. E.) Geology and ground-water resources of Desha and Lincoln Counties, Arkansas: Arkansas Geol. and Conserv. Comm. Water Resources Circ. 6, 129 p., 1961 [1962]. (Prepared in coop. with U. S. Geological Survey.)
1-63. (and TANAKA, H. H.) Effect of the Kirwin reservoir, Kansas, on ground-water levels [abs.]: Geol. Soc. America Spec. Paper 73, p. 111, 1963; Ground Water, Jour. Natl. Water Well Assoc., v. 1, no. 2, p. 41, 1963.
BEETEM, William Arthur
1-62. (and JANZER, V. J., and WAHLBERG, J. S.) Use of cesium-137 in the determination of cation-exchange capacity: U. S. Geol. Survey Bull. 1140-B, p. B1-B8, 1962.
1-63. Adsorption studies by the U. S.,Geological Survey, in The use of inorganic exchange materials for radioactive waste treatment: U. S. Atomic Energy Comm. Rept. TID-7644, p. 211-222; discussion, p. 223-225, 236, 1963.
BEIKMAN, Helen Marie
1-62. Geology of the Powder River Basin, Wyoming and Montana, with reference to subsurface disposal of radioactive wastes: U.S. Geol. Survey Rept. TEI-823 (open-file report), 85 p., 1962. (Report prepared for U. S. Atomic Energy Commission.)
BELL, Edwin A.
1-62. The ground-water situation in the Louisville area, Kentucky, 1945-61: Kentucky Geol. Survey, ser. 10, Inf. Circ. 10, 24 p., 1962. (Prepared by U. S. Geological Survey and Kentucky Geological Survey in coop. with Kentucky Dept. Commerce, Jefferson County and City of Louisville.)
BENNETT, Gordon D.
1-62. (and PATTEN, E. P., Jr.) Constant-head pumping test of a multiaquifer well to determine characteristics of individual aquifers: U. S. Geol. Survey Water-Supply Paper 1536-G, p. 181-203, 1962.
BENSON, Manuel A.
1-62. Discussion of "Progress in ground water studies with the electric-analog model": Am. Water Works Assoc. Jour., v. 54, no. 8, p. 956-957, 1962. (Discussion of a paper by R. H. Brown, same journal, p. 943-956.)
2-62. Factors influencing the occurrence of floods in a humid region of diverse terrain: U. S. Geol. Survey Water-Supply Paper 1580-B, p. B1-B64, 1962 [1963].

BENSON, Manuel A.--Continued
3-62. Plotting positions and economics of engineering planning: Am. Soc. Civil Engineers Proc., v. 88, Jour. Hydraulics Div., no. HY 6, pt. 1, p. 57-71, 1962.
1-63. Flood peaks related to hydrologic factors in the Southwest: Art. 229 in U. S. Geol. Survey Prof. Paper 450-E, p. E161-E163, 1963.
BERDAN, Jean Milton
1-63. Eccentricosta, a new Upper Silurian brachiopod genus: Jour. Paleontology, v. 37, no. 1, p. 254-256, 1963.
BERG, Henry Clay
1-63. (and HINCKLEY, D. W.) Reconnaissance geology of northern Baranof Island, Alaska: U. S. Geol. Survey Bull. 1141-O, p. O1-O24, 1963.
BERGIN, Marion Joseph
1-62. Coal geology of the Seitz quadrangle, Breathitt, Magoffin, Morgan, and Wolfe Counties, Kentucky: U. S. Geol. Survey Bull. 1122-C, p. C1-C39, 1962.
BERKSTRESSER, Charles F., Jr.
1-62. Study of the chemical character of natural water with modified stiff patterns [abs.]: Am. Geophys. Union Trans., v. 43, no. 4, p. 454, 1962; Ground Water, Jour. Natl. Water Well Assoc., v. 1, no. 2, p. 42, 1963.
1-63. Water-quality change with depth in some unconsolidated aquifers in central Wisconsin [abs.]: Geol. Soc. America Spec. Paper 73, p. 114, 1963; Ground Water, Jour. Natl. Water Well Assoc., v. 1, no. 2, p. 41, 1963.
BERMES, Boris John
1-63. (and LEVE, G. W., and TARVER, G. R.) Geology and ground-water resources of Flagler, Putnam, and St. Johns Counties, Florida: Florida Geol. Survey Rept. Inv. 32, 97 p., 1963. (Prepared by U. S. Geological Survey in coop. with Florida Geological Survey.)
2-63. (and LEVE, G. W., and TARVER, G. R.) Ground-water records of Flagler, Putnam, and St. Johns Counties, Florida: Florida Geol. Survey Inf. Circ. 37, 89 p., 1963. (Prepared by U. S. Geological Survey in coop. with Florida Geological Survey.)
BERRYHILL, Henry Lee, Jr.
1-62. (and SWANSON, V. E.) Revised stratigraphic nomenclature for Upper Pennsylvanian and Lower Permian rocks, Washington County, Pennsylvania: Art. 75 in U. S. Geol. Survey Prof. Paper 450-C, p. C43-C46, 1962.
BEUS, A. A.
1-62. Beryllium--Evaluation of deposits during prospecting and exploratory work: San Francisco, California, W. H. Freeman and Co., 161 p., 1962. (Edited by Lincoln R. Page; translated by F. Lachman; and preliminary editing by R. K. Harrison.)
BISSELL, Harold Joseph
1-63. Lake Bonneville--Geology of southern Utah Valley, Utah: U. S. Geol. Survey Prof. Paper 257-B, p. 101-130, 1963.
BLACK, Douglas F. B.
1-63. Geologic and structure map of a cryptoexplosion structure near Versailles, Kentucky: U. S. Geol. Survey open-file report, 1963.
BLACK, Rudolph Allan
1-62. (and FRISCHKNECHT, F. C., and HAZELWOOD, R. M., and JACKSON, W. H.) Geophysical methods of exploring for buried channels in the Monument Valley area, Arizona and Utah: U. S. Geol. Survey Bull. 1083-F, p. 161-228, 1962.
BLANCHETT, Jean
1-63. (and TYSON, N. S., and McGOWAN, E. F.) Aeromagnetic map of the Gaithersburg, and part of the Sandy Spring quadrangles, Montgomery County, Maryland: U. S. Geol. Survey Geophys. Inv. Map GP-395, 1963.
2-63. (and TYSON, N. S., and McGOWAN, E. F.) Aeromagnetic map of the Germantown and part of the Poolesville quadrangles, Montgomery and Frederick Counties, Maryland: U. S. Geol. Survey Geophys. Inv. Map GP-394, 1963.
3-63. (and TYSON, N. S., and McGOWAN, E. F.) Aeromagnetic map of the Rockville quadrangle, Montgomery County, Maryland, and Fairfax County, Virginia: U. S. Geol. Survey Geophys. Inv. Map GP-397, 1963.
4-63. (and TYSON, N. S., and McGOWAN, E. F.) Aeromagnetic map of the Seneca and part of the Sterling quadrangles, Montgomery County, Maryland, and Loudon and Fairfax Counties, Virginia: U. S. Geol. Survey Geophys. Inv. Map GP-396, 1963.
BLANK, H. Richard, Jr.
1-63. Ignimbrite vent in the Bull Valley district, Utah [abs.]: Geol. Soc. America Spec. Paper 73, p. 27, 1963.
2-63. (and COOPER, R. A., and WILLIS, I. A. G.) Basement rocks of the Koettlitz-Blue Glacier region, McMurdo Sound, Antarctica [abs.]: Geol. Soc. America Spec. Paper 73, p. 26-27, 1963.
BOETTCHER, Arnold J.
1-62. Records, logs, and water-level measurements of selected wells and test holes and chemical analyses of ground water in eastern Cheyenne and Kiowa Counties, Colorado: Colorado Water Conserv. Board Ground-Water Ser. Basic-Data Rept. 13, 18p., 1962. (Prepared by U. S. Geological Survey in coop. with Colorado Water Conservation Board.)
1-63. Prospects for irrigation in eastern Cheyenne and Kiowa Counties, Colorado: Colorado Water Conserv. Board Ground-Water Ser. Circ. 7, 12 p., 1963. (Prepared by U. S. Geological Survey in coop. with Colorado Water Conservation Board.)
2-63. Geology and ground-water resources in eastern Cheyenne and Kiowa Counties, Colorado, with a section on Chemical quality of the ground water, by C. A. Horr: U. S. Geol. Survey open-file report, 65 p., 1963.
BOGGESS, Durward H.
1-62. (and ADAMS, J. K.) Water-table, surface-drainage, and engineering soils map of the Middletown area, Delaware: U. S. Geol. Survey open-file report, 1962.

BOGGESS, Durward H.--Continued

2-62. (and ADAMS, J. K., and DAVIS, C. F.) Water-table, surface-drainage, and engineering soils map of the Smyrna area, Delaware: U. S. Geol. Survey open-file report, 1962.

3-62. (and RIMA, D. R.) Experiments in water spreading at Newark, Delaware: U. S. Geol. Survey Water-Supply Paper 1594-B, p. B1-B15, 1962.

1-63. (and ADAMS, J. K.) Water-table, surface-drainage, and engineering soils map of the Greenwood area, Delaware: U. S. Geol. Survey open-file report, 1963.

2-63. (and ADAMS, J. K., and COSKERY, O. J.) Water-table, surface-drainage, and engineering soils map of the Milton area, Delaware: U. S. Geol. Survey open-file report, 1963.

3-63. (and ADAMS, J. K.) Water-table, surface-drainage, and engineering soils map of the Seaford West area, Delaware: U. S. Geol. Survey open-file report, 1963.

4-63. (and ADAMS, J. K., and DAVIS, C. F.) Water-table, surface-drainage, and engineering soils map of the Georgetown area, Delaware: U. S. Geol. Survey open-ile report, 1963.

5-63. (and ADAMS, J. K., and DAVIS, C. F.) Water-table, surface-drainage, and engineering soils map of the Rehoboth Beach area, Delaware: U.,S. Geol. Survey open-file report, 1963.

BOGUE, Richard G.

1-61. Celestite deposits near Thano Bula Khan, Hyderabad Division, West Pakistan: Pakistan Geol. Survey Mineral Inf. Circ. (Quetta), no. 2, 20 p., 1961.

2-61. Cost estimate for concentrating low-grade chromite ore, Hindubagh mining district, West Pakistan: Pakistan Geol. Survey Mineral Inf. Rept. (Quetta), no. 1, 18 p., 1961.

3-61. Fuller's earth deposits, Thano Bula Khan, Dadu District, Hyderabad Division, West Pakistan: Pakistan Geol. Survey Mineral Inf. Circ. (Quetta), no. 1, 15 p., 1961.

BOOKS, Kenneth Garry

1-62. Aeroradioactivity survey and related surface geology of parts of the Los Angeles region, California (ARMS-I): U. S. Atomic Energy Comm. Rept. CEX-59.4.16, 25 p., 1962. (Report prepared for U. S. Atomic Energy Commission, Civil Effects Test Operations series, by U. S. Geological Survey.)

BOSWELL, Ernest H.

1-62. Cretaceous aquifers of northeastern Mississippi: U. S. Geol. Survey open-file report, 494 p., 1962.

2-62. (and ELLISON, B. E., Jr., and HARVEY, E. J.) Interim report on ground-water study in Alcorn County, Mississippi: U. S. Geol. Survey open-file report, 48 p., 1962.

1-63. (and ELLISON, B. E., Jr., and HARVEY, E. J.) Interim report on ground-water study in Alcorn County, Mississippi: Mississippi Board Water Comm. Bull. 63-3, 39 p., 1963. (Prepared by U. S. Geological Survey in coop. with City of Corinth and Mississippi Board Water Commissioners.)

BOWLES, C. Gilbert

1-62. (and GARD, L. M., Jr.) Minor elements in evaporite rocks of the Gnome drift: U. S. Atomic Energy Comm. Rept. PNE-130F, p. 53-67, 1962. (Report prepared for U. S. Atomic Energy Commission by U. S. Geological Survey for Project Gnome.)

BOWSHER, Arthur Leroy

1-61. The stratigraphic occurrence of some lower Mississippian corals from New Mexico and Missouri: Jour. Paleontology, v. 35, no. 5, p. 955-962, 1961.

BRADLEY, Edward

1-62. Relation of surface and ground water in the Souris River Valley near Minot, North Dakota: U. S.,Geol. Survey open-file report, 12 p., 1962.

BRADLEY, Wilmot Hyde

1-62. (and FAHEY, J. J.) Occurrence of stevensite in the Green River Formation of Wyoming: Am. Mineralogist, v. 47, nos. 7-8, p. 996-998, 1962.

1-63. Paleolimnology, Chap. 23 in Frey, D. G., ed., Limnology in North America: Madison, Univ. Wisconsin Press, p. 621-652, 1963.

BRAMKAMP, Richard Allan

1-62. (and BROWN, G. F., and HOLM, D. A., and LAYNE, N. M., Jr.) Geographic map of the Wadi As Sirhan quadrangle, Kingdom of Saudi Arabia: U. S. Geol. Survey Misc. Geol. Inv. Map I-200 B, 1962.

1-63. (and RAMIREZ, L. F., and BROWN, G. F., and POCOCK, A. E.) Geologic map of the Wadi Ar Rimah quadrangle, Kingdom of Saudi Arabia: U. S. Geol. Survey Misc. Geol. Inv. Map I-206 A, 1963.

BREGER, Irving Arthur

1-62. (and BROWN, Andrew) Kerogen in the Chattanooga shale: Science, v. 137, no. 3525, p. 221-224, 1962.

BRENNAN, Robert

1-63. Reconnaissance study of the chemical quality of surface waters in the Sacramento River basin, California: U. S. Geol. Survey Water-Supply Paper 1619-Q, p. Q1-Q44, 1963.

BREW, David Alan

1-62. Mechanics of a small landslide block, Wattener Lizum, Austria: Geol. Soc. America Bull., v. 73, no. 10, p. 1277-1279, 1962.

BRIGGS, Reginald Peter

1-62. (and GELABERT, P. A.) Preliminary report of the geology of the Barranquitas quadrangle, Puerto Rico: U. S. Geol.,Survey Misc. Geol. Inv. Map I-336, 2 sheets, 1962. (Prepared in coop. with Economic Development Administration, Commonwealth Puerto Rico.)

BROBST, Donald Albert

1-62. Geology of the Spruce Pine district, Avery, Mitchell, and Yancey Counties, North Carolina: U. S. Geol.,Survey Bull. 1122-A, p. A1-A26, 1962.

BROEKER, Margaret E.

1-63. (and WINSLOW, J. D.) Ground-water levels in observation wells in Kansas, 1962: U. S. Geol. Survey open-file report, 400 p., 1963.

BROKAW, Arnold Leslie

1-62. (and GOTT, G. B., and MABEY, D. R., and McCARTHY, J. H., Jr., and ODA, Uteana) Mineralization associated with a magnetic anomaly in part of the Ely quadrangle, Nevada: U. S. Geol. Survey Circ. 475, 7 p., 1962.

1-63. (and GOTT, G. B., and MABEY, D. R., and McCARTHY, J. H., Jr.) Coincident geochemical and magnetic anomalies in the central Egan Range, White Pine County, Nevada [abs.]: Mining Eng., v. 15, no. 1, p.,60-61, 1963.

2-63. (and GOTT, G. B., and MABEY, D. R., and McCARTHY, J. H., Jr., and ODA, Uteana) Mineralization associated with a magnetic anomaly in part of the Ely quadrangle, Nevada: Art. 180 in U. S. Geol. Survey Prof. Paper 450-E, p. E1-E8, 1963.

BROMERY, Randolph Wilson

1-62. Aeromagnetic and gravimetric interpretation of the geology of the Malone, Rochester, Pe Ell, and Adna quadrangles, Pacific, Lewis, Grays Harbor, and Thurston Counties, Washington: Masters Abs., v. 1, no. 2, p. 13, 1962.

2-62. Geologic interpretation of the aeromagnetic map of the Lebanon quadrangle, Linn and Marion Counties, Oregon: U. S. Geol. Survey Geophys. Inv. Map GP-212, 1962.

3-62. (and GILBERT, F. P.) Aeromagnetic map of the Mt. Cube quadrangle and part of the Rumney quadrangle, Grafton County, New Hampshire, and Orange and Windsor Counties, Vermont: U. S. Geol. Survey Geophys. Inv. Map GP-297, 1962.

4-62. (and GILBERT, F. P.) Aeromagnetic map of the Skinner and parts of the Attean and Sandy Bay quadrangles, Somerset and Franklin Counties, Maine: U. S. Geol. Survey Geophys. Inv. Map GP-310, 1962.

1-63. (and GALAT, G. A., and CHANDLER, E. J.) Aeromagnetic map of the Quantico quadrangle, Prince William and Stafford Counties, Virginia: U. S. Geol. Survey Geophys. Inv. Map GP-391, 1963.

2-63. (and GALAT, G. A., and GILBERT, F. P.) Aeromagnetic map of the Belmont quadrangle, Orange and Spotsylvania Counties, Virginia: U. S. Geol. Survey Geophys. Inv. Map GP-387, 1963.

3-3. (and GALAT, G. A., and GILBERT, F. P.) Aeromagnetic map of the Contrary Creek quadrangle, Louisa and Spotsylvania Counties, Virginia: U. S. Geol. Survey Geophys. Inv. Map GP-389, 1963.

4-63. (and GALAT, G. A., and GILBERT, F. P) Aeromagnetic map of the Lahore quadrangle, Louisa, Spotsylvania, and Orange Counties, Virginia: U. S. Geol. Survey Geophys. Inv. Map GP-386, 1963.

5-63. (and GALAT, G. A., and GILBERT, F. P.) Aeromagnetic map of the Mineral quadrangle, Louisa, Spotsylvania, and Orange Counties, Virginia: U. S. Geol. Survey Geophys. Inv. Map GP-388, 1963.

6-63. (and GILBERT, F. P., and others) Aeromagnetic map of the Beltsville quadrangle, Montgomery and Prince Georges Counties, Maryland: U. S. Geol. Survey Geophys. Inv. Map GP-399, 1963.

7-63. (and GILBERT, F. P., and others) Aeromagnetic map of the Kensington quadrangle, Montgomery County, Maryland: U. S. Geol. Survey Geophys. Inv. Map GP-398, 1963.

8-63. (and LONG, C. L., and others) Aeromagnetic map of the Stacyville quadrangle and part of the Katahdin quadrangle, Penobscot and Piscataquis Counties, Maine: U. S. Geol. Survey Geophys. Inv. Map GP-336, 1963.

9-63. (and McGOWAN, E. F., and others) Aeromagnetic map of the Chesuncook quadrangle, Piscataquis County, Maine: U. S. Geol. Survey Geophys. Inv. Map GP-379, 1963.

10-63. (and McGOWAN, E. F., and others) Aeromagnetic map of part of the Churchill Lake quadrangle, Piscataquis County, Maine: U. S. Geol. Survey Geophys. Inv. Map GP-375, 1963.

11-63. (and McGOWAN, E. F., and others) Aeromagnetic map of the Telos Lake quadrangle, Piscataquis County, Maine: U. S. Geol. Survey Geophys. Inv. Map GP-380, 1963.

12-63. (and TYSON, N. S., and others) Aeromagnetic map of part of the Caucomgomoc Lake quadrangle, Somerset and Piscataquis Counties, Maine: U. S. Geol. Survey Geophys. Inv. Map GP-378, 1963.

13-63. (and TYSON, N. S., and others) Aeromagnetic map of the Stratton quadrangle, Franklin and Somerset Counties, Maine: U. S. Geol. Survey Geophys. Inv. Map GP-333, 1963.

14-63. (and VARGO, J. L., and others) Aeromagnetic map of the Greenville quadrangle and part of the Sebec Lake quadrangle, Piscataquis and Somerset Counties, Maine: U. S. Geol. Survey Geophys. Inv. Map GP-335, 1963.

15-63. (and GALAT, G. A., and CHANDLER, E. J.) Aeromagnetic map of the Joplin quadrangle, Prince William and Stafford Counties, Virginia: U. S. Geol. Survey Geophys. Inv. Map GP-390, 1963.

16-63. (and SODAY, H. J., and others) Aeromagnetic map of the Spencer Lake quadrangle, Franklin and Somerset Counties, Maine: U. S. Geol. Survey Geophys. Inv. Map GP-331, 1963.

17-63. (and TYSON, N. S., and others) Aeromagnetic map of part of the Traveler Mountain quadrangle, Piscataquis and Penobscot Counties, Maine: U. S. Geol. Survey Geophys. Inv. Map GP-381, 1963.

BROMFIELD, Calvin Stanton

1-62. Geology of the Wilson Peak stock, San Miguel Mountains, Colorado: U. S. Geol. Survey open-file report, 154 p., 1962.

1-63. Geology of the Wilson Peak stock, San Miguel Mountains, Colorado [abs.]: Dissert. Abs., v. 23, no. 7, p. 2490, 1963.

BROOM, Matthew E.

1-62. Sources of potable water supplies for the U. S. National Park Service recreation area, Crawford Dam and Reservoir Site, Delta County, Colorado: U. S. Geol. Survey open-file report, 15 p., 1962.

BROOM, Matthew E.--Continued

1-63. (and IRWIN, J. H.) Records, logs, and water-level measurements of selected wells and test holes, and chemical analyses of ground water in Bent County, Colorado: U. S. Geol. Survey open-file report, 62 p., 1963.

2-63. (and IRWIN, J. H.) Records, logs, and water-level measurements of selected wells and test holes, and chemical analyses of ground water in Bent County, Colorado: Colorado Water Conserv. Board Basic-Data Rept. 14, 40 p., 1963. (Prepared by U. S. Geological Survey in coop. with Colorado Water Conservation Board.)

BROSGÉ, William Peters

1-62. (and DUTRO, J. T., Jr., and MANGUS, M. D., and REISER, H. N.) Paleozoic sequence in eastern Brooks Range, Alaska: Am. Assoc. Petroleum Geologists Bull., v. 46, no. 12, p. 2174-2198, 1962.

2-62. (and WHITTINGTON, C. L., and others) Preliminary geologic map of the Umiat-Maybe Creek region, Alaska: U. S. Geol. Survey open-file report, 3 sheets, 1962. (Superseded by Brosgé, W. P., 1-63.)

1-63. (and WHITTINGTON, C. L.) Preliminary geologic map of the Umiat-Maybe Creek region, Alaska: U. S. Geol. Survey open-file report, 1 map (2 sheets), 1 explanation sheet, 1963. (Supersedes Brosgé, W. P., 2-62.)

BROWN, Andrew

1-62. Geology and the Gettysburg campaign: Pennsylvania Topog. and Geol. Survey Educ. Ser., no. 5, 15 p., [1962]. (Reprinted from GeoTimes, v. 6, no. 1, 1961.)

1-63. A geologist-general in the Civil War: GeoTimes, v. 7, no. 7, p. 8-11, 1963.

BROWN, Delbert Wayne

1-62. (and KENNER, W. E., and CROOKS, J. W., and FOSTER, J. B.) Water resources of Brevard County, Florida: Florida Geol. Survey Rept. Inv. 28, 104 p., 1962.

BROWN, Philip Monroe

1-63. (and JOHNSTON, J. E., and BERGQUIST, H. R.) Evidence of a marine Cretaceous basin in northeastern North Carolina [abs.]: Geol. Soc. America Spec. Paper 73, p. 124-125, 1963.

BROWN, Richmond Flint

1-62. (and LAMBERT, T. W.) Availability of ground water in Allen, Barren Edmonson, Green, Hart, Logan, Metcalfe, Monroe, Simpson, and Warren Counties, Kentucky--Sheet 1, Geologic map; sheet 2, Ground water; sheet 3, Generalized columnar section: U. S. Geol. Survey Hydrol. Inv. Atlas HA-32, 1962. (Prepared in coop. with Kentucky Department Economic Development and Kentucky Geological Survey.)

1-63. (and COTTER, R. D.) Water and the Minnesota Iron Range: U. S. Geol. Survey open-file report, 16 p., 1963.

2-63. (and LAMBERT, T. W.) Availability of ground water in Breckinridge, Grayson, Hardin, Larue, and Meade Counties, Kentucky--Sheet 1, Geologic map; sheet 2, Ground water; sheet 3, Generalized columnar section: U. S. Geol. Survey Hydrol. Inv.,Atlas HA-33, 1963. (Prepared in coop. with Kentucky Geological Survey and Kentucky Department Economic Development.)

3-63. (and LAMBERT, T.,W.) Reconnaissance of ground-water resources in the Mississippian Plateau region, Kentucky: U. S. Geol. Survey Water-Supply Paper 1603, 58 p., 1963.

BROWN, Roland Wilbur

1-62. Paleocene flora of the Rocky Mountains and Great Plains: U. S. Geol. Survey Prof. Paper 375, 119 p., 1962.

BROWN, Russell Hayward

1-62. Progress in ground water studies with the electric-analog model: Am. Water Works Assoc. Jour., v. 54, no. 8, p. 943-956, 1962. (Discussion by M. A. Benson, same journal, p.,956-957.)

BROWN, Stuart G.

1-62. Possibilities for future water-resources development at Fort Huachuca, Arizona: Arizona Watershed Symposium, 6th Ann., Sept. 18, 1962, Proc., p. 20-21, 1962.

2-62. (and NEWCOMB, R. C.) Ground-water resources of Cow Valley, Malheur County, Oregon: U. S. Geol. Survey Water-Supply Paper 1619-M, p. M1-M38, 1962.

1-63. (and NEWCOMB, R. C.) Ground-water resources of the coastal sand-dune area north of Coos Bay, Oregon: U. S. Geol. Survey Water-Supply Paper 1619-D, p. D1-D32, 1963.

2-63. Problems of utilizing ground water in the west-side business district of Portland, Oregon: U. S. Geol. Survey Water-Supply Paper 1619-C, p. O1-O42, 1963.

BRYANT, Bruce Hazelton

1-62. Geology of the Linville quadrangle, North Carolina-Tennessee--A preliminary report: U. S. Geol. Survey Bull. 1121-D, p. D1-D30, 1962.

BUCKMASTER, James L.

1-63. (and LOVING, H. B., and DANDO, T. O.) Airborne control system: Art. 218 in U. S. Geol. Survey Prof. Paper 450-E, p. E133-E135, 1963.

2-63. (and MURPHY, W. D.) Portable surveying tower: Art.,217 in U. S. Geol. Survey Prof.,Paper 450-E, p. E131-E132, 1963.

BUDDINGTON, Arthur Francis

1-61. (and BALSLEY, J. R., Jr.) Microintergrowths and fabric of iron-titanium oxide minerals in some Adirondack rocks, in Krishnan, M. S., ed., Mahadevan volume--A collection of geological papers in commemoration of the sixtyfirst birthday of Prof. C. Mahadevan: Hyderabad, India, Pub. Comm., p. 1-16, 1961.

2-61. Iron and iron-titanium oxide minerals and concentrations of Precambrian rocks of New York and New Jersey, U.S.A., in Fiziko-khimicheskie problemy formirovaniya gornykh porod i rod, V. 1: Moscow, Akad. Nauk SSSR, Inst. Geologii Rudnykh Mestorozhdenii, Petrografii, Mineralogii i Geokhimii, p. 234-263, 1961. (Russian text with English summary.)

BUDDINGTON, Arthur Francis--Continued

1-62. (and LEONARD, B. F., 3d) Regional geology of the St. Lawrence County magnetite district, northwest Adirondacks, New York: U. S. Geol. Survey Prof. Paper 376, 145 p., 1962 [1963].

1-63. (and FAHEY, J. J., and VLISIDIS, A. C.) Degree of oxidation of Adirondack iron oxide and iron-titanium oxide minerals in relation to petrogeny: Jour. Petrology (Oxford, England), v. 4, no. 1, p. 138-169, 1963.

BUE, Conrad Dahl

1-63. Principal lakes of the United States: U. S. Geol. Survey Circ. 476, 22 p., 1963.

BULL, William Benham

1-62. Map showing land subsidence due to artesian-head decline, 1943-59, Los Banos-Kettleman City area, California: U. S. Geol. Survey open-file report, 1962.

2-62. Map showing minimum elevation of the piezometric surface of the lower water-bearing zone as of 1960, Los Banos-Kettleman City area, California: U. S. Geol. Survey open-file report, 1962.

1-63. Alluvial-fan deposits in western Fresno County, California: Jour. Geology, v. 71, no. 3, p. 243-251, 1963.

2-63. Tectonic history as related to terraces and alluvial-fan segments in western Fresno County, California [abs.]: Geol. Soc. America Spec. Paper 73, p. 29, 1963.

BUNCH, Clyde M.

1-62. (and PRICE, McGlone) Floods in Georgia, magnitude and frequency: U. S. Geol. Survey open-file report, 152 p., 1962.

BUNKER, Carl Maurice

1-62. Gamma-radioactivity measurements of drill holes, wells, and the Gnome drift: U. S. Atomic Energy Comm. Rept.,PNE-130F, p. 91-111, 1962. (Report prepared for U. S. Atomic Energy Commission by U. S. Geological Survey for Project Gnome.)

2-62. (and BRADLEY, W. A.) Gamma-radioactivity investigations related to waste disposal, Jackass Flats, Nevada Test Site, Nevada: U. S. Geol. Survey Rept. TEI-829 (open-file report), 19 p., 1962. (Report prepared for U. S. Atomic Energy Commission.)

3-62. (and SHUTLER, M. D.) Gamma-radioactivity investigations at the Nevada Test Site, Nye County, Nevada--Interim report, February 1960 to July 1961: U. S. Geol. Survey Rept. TEI-832 (open-file report), 62 p., 1962. (Report prepared for U. S. Atomic Energy Commission.)

BURNHAM, Willis L.

1-63. (and KUNKEL, Fred, and HOFMANN, Walter, and PETERSON, W. C.) Hydrogeologic reconnaissance of San Nicolas Island, California: U. S. Geol. Survey Water-Supply Paper 1539-O, p. O1-O43, 1963.

BYERS, Frank Milton, Jr.

1-63. (and ORKILD, P. P., and CARR, W. J., and CHRISTIANSEN, R. L.) Timber Mountain caldera, Nevada Test Site and vicinity [abs.]: Am. Geophys. Union, Trans., v. 44, no. 1, p. 113, 1963.

CADIGAN, Robert Allen

1-62. A method for determining the randomness of regionally distributed quantitative geologic data: Jour. Sed. Petrology, v. 32, no. 4, p. 813-818, 1962.

CADY, Wallace Martin

1-61. (leader) Excursion across the Green Mountains--Hinesburg to Montpelier, Trip A-1, in New England Intercollegiate Geol. Conf., Vermont Geologic Map Centennial, 53d Ann. Mtg., Oct. 13-15, 1961, Guidebook, sec. 1, 5 p., 1961.

1-62. (and ALBEE, A. L., and MURPHY, J. F.) Bedrock geology of the Lincoln Mountain quadrangle, Vermont: U. S. Geol. Survey Geol. Quad. Map GQ-164, 1962.

CAGLE, Joseph W., Jr.

1-63. (and NEWTON, J. G.) Geology and ground-water resources of Escambia County, Alabama: U. S. Geol. Survey open-file report, 392 p., 1963.

CALKINS, Frank Cathcart

1-62. Two implements for handling small quantities of liquid: Art. 102 in U. S. Geol. Survey Prof. Paper 450-C, p. C105-C107, 1962.

CALLAHAN, James A.

1-63. Ground-water resources in Yazoo County, Mississippi: Mississippi Board Water Comm. Bull. 63-5, 42 p., 1963. (Prepared by U. S. Geological Survey in coop. with Mississippi Board of Water Commissioners.)

2-63. (and SKELTON, John, and EVERETT, D. E., and HARVEY, E. J.) Water resources of Adams, Claiborne, Jefferson, and Warren Counties, Mississippi: Mississippi Indus. and Technol. Research Comm. Water Research Bull. 63-1, 48 p., 1963. (Prepared in coop. with U. S. Geological Survey.)

CALLAHAN, Joseph Thomas

1-62. Recent developments in the conservation of ground water, in Minerals and energy--Problems, practices, and goals, Western Resources Conference, 1962: Colorado School Mines Quart., v. 57, no. 4, pt. 1, p.,131-138, 1962 [1963].

2-62. (and WAIT, R. L., and McCOLLUM, M. J.) Television--A new tool for the ground-water geologist: Georgia Mineral Newsletter, v. 15, nos. 1-2, p. 22-25, 1962.

1-63. Yield of sedimentary aquifers of the Coastal Plain river basins in the southeastern States [abs.]: Geol. Soc. America Spec. Paper 73, p. 3, 1963.

CAMPBELL, Arthur Byron

1-63. (and GOOD, S. E.) Geology and mineral deposits of Twin Crags quadrangle, Idaho: U. S. Geol. Survey Bull. 1142-A, p. A1-A32, 1963.

CANNEY, Frank Cogswell

1-63. Soil sampling experiments in the Mission Mine area, Pima County, Arizona [abs.]: Mining Eng., v. 15, no. 1, p. 61, 1963.

CANNON, Helen Leighton
1-62. Biogeochemistry of vanadium: U. S. Geol. Survey open-file report, 14 p., 1962.
2-62. (and BOWLES, J. M.) Contamination of vegetation by tetraethyl lead: Science, v. 137, no. 3532, p. 765-766, 1962.
CANNON Ralph Smyser, Jr.
1-62. (and PIERCE, A. P., and ANTWEILER, J. C., and BUCK, K. L.) Lead-isotope studies in the northern Rockies, U.S.A., in Petrologic studies--A volume in honor of A. F. Buddington: New York, New York, Geol. Soc. America, p. 115-131, 1962.
1-63. (and BUCK, K. L., and PIERCE, A. P.) Sampling a zoned galena crystal for lead isotope study: Art. 199 in U. S. Geol. Survey Prof. Paper 450-E, p. E73-E77, 1963.
CARLSON, John E.
1-63. (and MABEY, D. R.) Gravity and aeromagnetic maps of the Ely area, White Pine County, Nevada: U. S. Geol. Survey Geophys. Inv. Map GP-392, 1963.
CARLSTON, Charles William
1-62. Character and history of the upper Ohio River valley: U. S. Geol. Survey Bull. 1141-I, p. I1-I10, 1962.
2-62. (and THATCHER, L. L.) Tritium studies in the United States Geological Survey, in Tritium in the physical and biological sciences, V. 1: Internat. Atomic Energy Agency, Symposium on the detection and use of tritium in the physical and biological sciences, Vienna, May 3-10, 1961, Proc., p. 75-81, 1962.
1-63. An early American statement of the Badon Ghyben-Herzberg principle of static fresh-water-salt-water balance: Am. Jour. Sci., v. 261, no. 1, p. 88-91, 1963.
CARPENTER, Carl H.
1-63. (and YOUNG, R. A.) Ground-water data, central Sevier Valley, parts of Sanpete, Sevier, and Piute Counties, Utah: Utah State Engineer Basic-Data Rept. 3, 34 p., 1963.
2-63. (and YOUNG, R. A.) Records of selected wells and springs, chemical analyses of ground water, water-level measurements of selected wells, selected drillers' logs of wells, and logs of test holes, Central Sevier Valley, Sanpete, Sevier, and Piute Counties, Utah: U. S. Geol. Survey open-file report, 29 p., 1963.
CARR, Michael H.
1-62. A shock-wave technique for determination of densities at high pressures using strain gages [abs.]: Am. Geophys. Union Trans., v. 43, no. 4, p. 455-456, 1962.
1-63. Shock equation of state, in Astrogeologic studies--Annual progress report, Aug. 25, 1961 to Aug. 24, 1962, Pt. B, Crater investigations: U. S. Geol. Survey open-file report, p. 102-106, 1963.
CARR, Wilfred James
1-63. (and TRIMBLE, D. E.) Geology of the American Falls quadrangle, Idaho: U. S. Geol. Survey Bull. 1121-G, p. G1-G44, 1963.
CARROLL, Dorothy
1-62. Rainwater as a chemical agent of geologic processes--A review: U. S. Geol. Survey Water-Supply Paper 1535-G, p. G1-G18, 1962.
2-62. Soils and rocks of the Oak Ridge area, Tennessee: U. S. Geol. Survey Rept. TEI-785 (open-file report), 33 p., 1962. (Report prepared for U. S. Atomic Energy Commission.)
3-62. Vermiculite in sea water [abs.]: Natl. Conf. Clays and Clay Minerals, 11th, Ottawa, 1962, Program and Abs., p. 17-18, 1962.
1-63. Chlorite in sediments off the Atlantic Coast of the United States [abs.]: Geol. Soc. America, Southeastern Sec., Ann. Mtg., Roanoke, Virginia, Apr. 1963, Program, p. 17-18, 1963.
CARROLL, Roderick D.
1-62. (and DICKEY, D. D.) Seismic determination of elastic constants of rock salt, Gnome drift: U. S. Atomic Energy Comm. Rept. PNE-130F, p. 85-90, 1962. (Report prepared for U. S. Atomic Energy Commission by U. S. Geological Survey for Project Gnome.)
CARTER, William Douglas
1-63. Unconformity marking the Jurassic-Cretaceous boundary in the La Ligua area, Aconcagua Province, Chile: Art. 196 in U. S. Geol. Survey Prof. Paper 450-E, p. E61-E63, 1963.
CASE, James E.
1-63. (and JOESTING, H. R., and BYERLY, P. E.) Regional geophysical investigations in the La Sal Mountains area, Utah and Colorado: U. S. Geol. Survey Prof. Paper 316-F, p. 91-116, 1963.
CATANZARO, Edward John
1-63. Zircon ages in southwestern Minnesota: Jour. Geophys. Research, v. 68, no. 7, p. 2045-2048, 1963.
CATER, Frederick William, Jr.
1-63. (and ELSTON, D. P.) Structural development of salt anticlines of Colorado and Utah, in Backbone of the Americas: Am. Assoc. Petroleum Geologists Mem. 2, p. 152-159, 1963.
CATHCART, James Bachelder
1-63. Economic geology of the Keysville quadrangle, Florida: U. S. Geol. Survey Bull. 1128, 82 p., 1963.
CATTERMOLE, John Marcus
1-62. (and HANSEN, W. R.) Geologic effects of the high-explosive tests in the USGS Tunnel area, Nevada Test Site: U. S. Geol., Survey Prof. Paper 382-B, p. B1-B31, 1962 [1963].
1-63. (and WIESNET, D. R.) Exposure of the post-Knox unconformity in Beaver Valley, Knox County, Tennessee [abs.]: Geol. Soc. America Spec. Paper 73, p. 127, 1963.
2-63. Geology of the Burkesville quadrangle, Kentucky: U. S. Geol. Survey Geol. Quad. Map GQ-220, 1963. (Prepared in coop. with Kentucky Geological Survey.)
CEDERSTROM, Dagfin John
1-62. (and TRAINER, F. W., and WALLER, R. M.) Geology and ground-water resources in the Anchorage area, Alaska: U. S. Geol. Survey open-file report, 196 p., 1962.
CHAMBERLAIN, James E.
1-63. (and MANNELLO, L. R.) New developments in topographic mapping techniques, in Econ. Comm. Asia and Far East (ECAFE), Sub.-Comm. on Mineral Resources Devel., 2d Symposium on the Development of the Petroleum Resources of Asia and the Far East--U. S. Contr.: Washington, D. C., U. S. Dept. of the Interior, p. 77-93, 1962.
CHAO, Edward Ching-Te
1-62. (and ADLER, Isidore, and DWORNIK, E. J., and LITTLER, Janet) Metallic spherules in tektites from Isabela, the Philippine Islands, in Astrogeologic studies--Semiannual progress report, Feb. 26, 1961 to Aug. 24, 1961: U. S. Geol. Survey open-file report, p. 6-14, 1962.
2-62. (and LITTLER, Janet) The petrography of impactites and tektites with special reference to a dense impactite glass from the Ries crater, Germany [abs.]: Jour. Geophys. Research, v. 67, no. 9, p. 3548-3549, 1962.
1-63. Geological occurrences of some southeast Asian and Australian tektites [abs.]: Am. Geophys. Union Trans., v. 44, no. 1, p. 93, 1963.
2-63. (and LITTLER, Janet) Additional evidence for the impact origin of the Ries basin, Bavaria, Germany [abs.]: Geol. Soc. America Spec. Paper 73, p. 127, 1963.
3-63. Dense glass from the Ries Crater of southern Germany, in Astrogeologic studies--Annual progress report, Aug. 25, 1961 to Aug. 24, 1962, Pt. C, Cosmochemistry and petrography: U. S. Geol. Survey open-file report, p. 103-114, 1963.
4-63. Geological occurrences of some Southeast Asian and Australian tektites, in Astrogeologic Studies--Annual progress report, Aug. 25, 1961 to Aug. 24, 1962, Pt. C, Cosmochemistry and petrography: U. S. Geol. Survey open-file report, p. 101-102, 1963.
5-63. The petrographic and chemical characteristics of tektites, in Astrogeologic studies--Annual progress report, Aug. 25, 1961 to Aug. 24, 1962, Pt. C, Cosmochemistry and petrography: U. S. Geol. Survey open-file report, p. 8-100, 1963.
6-63. (and FAHEY, J. J., and LITTLER, Janet, and MILTON, D. J.) Stishovite, $SiO_2$, a very high pressure new mineral from Meteor Crater, Arizona, in Astrogeologic studies--Annual progress report, Aug. 25, 1961 to Aug. 24, 1962, Pt. B, Crater investigations: U. S. Geol. Survey open-file report, p. 10-17, 1963.
CHAPMAN, Howard T.
1-62. (and ROBINSON, A. E.) A thermal flowmeter for measuring velocity of flow in a well: U. S. Geol. Survey Water-Supply Paper 1544-E, p. E1-E12, 1962.
CHAPMAN, Robert Mills
1-63. (and COATS, R. R., and PAYNE, T. G.) Placer tin deposits in central Alaska: U. S. Geol. Survey open-file report, 53 p., 1963.
CHAPMAN, William H.
1-62. Field control for Antarctic mapping: Am. Soc. Civil Engineers Proc., v. 88, Jour. Surveying and Mapping Div., no. SU 1, p. 29-39, 1962.
CHEMERYS, Joseph C.
1-62. (and PHIBBS, E. J., Jr.) Chemical and physical character of surface waters of North Carolina, 1958-59: North Carolina Dept. Water Resources, Div. Stream Sanitation and Hydrology Bull. 1, v. 3, 180 p., 1962. (Prepared by U. S. Geological Survey in coop. with North Carolina Dept. Water Resources.)
CHIDESTER, Alfred Herman
1-61. (leader) Economic geology of the Belvidere Mountain asbestos area, Vermont Asbestos Mines, Division of the Ruberoid Company, Trip B-1, in New England Intercollegiate Geol. Conf., Vermont Geologic Map Centennial, 53d Ann. Mtg., Oct. 13-15, 1961, Guidebook, sec. 3, 2 p., 1961.
1-62. Petrology and geochemistry of selected talc-bearing ultramafic rocks and adjacent country rocks in north-central Vermont: U. S. Geol. Survey Prof. Paper 345, 207 p., 1962.
2-62. (and WORTHINGTON, H. W.) Talc and soapstone in the United States, exclusive of Alaska and Hawaii: U. S. Geol. Survey Mineral Inv. Resource Map MR-31, 1962.
CHILDS, Orlo Eckersley
1-63. Place of tectonic concepts in geological thinking, in Backbone of the Americas: Am. Assoc. Petroleum Geologists Mem. 2, p. 1-3, 1963.
2-63. Career opportunities in geology: Am. Assoc. Petroleum Geologists Bull., v. 47, no. 5, p. 856-865, 1963; abs., Am. Assoc. Petroleum Geologists Pacific Sec., 38th Ann. Mtg., Los Angeles, California, Apr. 1963, Program, p. 29, 1963.
CHORLEY, Richard J.
1-62. Geomorphology and general systems theory: U. S. Geol. Survey Prof. Paper 500-B, p. B1-B10, 1962.
CHRIST, Charles Louis
1-62. Nature of the polyions in hydrated borate crystals: Internat. Conf. Coordination Chemistry, 7th, Stockholm and Uppsala, Sweden, June 1962 Proc., p. 178-180, 1962.
CLARK, Joan Robinson
1-62. (and CHRIST, C. L., and APPLEMAN, D. E.) Studies of borate minerals --[Pt.] 10, The crystal structure of $CaB_3O_5(OH)$: Acta. Cryst., v. 15, pt. 3, p. 207-213, 1962.
CLARK, William Evans
1-62. (and MUSGROVE, R. H., and MENKE, C. G., and CAGLE, J. W., Jr.) Hydrology of Brooklyn Lake near Keystone Heights, Florida: U. S. Geol. Survey open-file report, 49 p., 1962.
2-62. (and MUSGROVE, R. H., and MENKE, C. G., and CAGLE, J. W., Jr.) Interim report on the water resources of Alachua, Bradford, Clay, and Union Counties, Florida: Florida Geol. Survey Inf. Circ. 36,

CLARK, William Evans--Continued
92 p., 1962. (Prepared by U. S. Geological Survey in coop. with Florida Geological Survey.)
3-62. (and MUSGROVE, R. H., and MENKE, C. G., and CAGLE, J. W., Jr.) Water-resources data for Alachua, Bradford, Clay, and Union Counties, Florida: U. S. Geol. Survey open-file report, 162 p., 1962.
1-63. (and MUSGROVE, R. H., and MENKE, C. G., and CAGLE, J. W., Jr.) Water resources of Alachua, Bradford, Clay, and Union Counties, Florida: U. S. Geol. Survey open-file report, 186 p., 1963.
2-63. Evapotranspiration and the relation of ground water to surface water in the Pond Creek basin, Oklahoma: Art. 221 in U. S. Geol. Survey Prof. Paper 450-E, p. E142-E145, 1963.

CLARKE, Alva B.
1-62. A photographic edge-isolation technique: Photogramm. Eng., v. 28, no. 3, p. 393-399, 1962.
2-62. Edge isolation in photogrammetry and geologic photography: Art. 166 in U. S. Geol. Survey Prof. Paper 450-D, p. D160-D163, 1962.

CLARKE, Frank E.
1-62. Evaluation and control of water-well corrosion problems in Kharga and Dakhla Oases, Western Desert, Egypt, U. A. R.: U. S. Geol. Survey open-file report, 61 p., 1962.

CLARKE, James Wood
1-62. (and VITALIANO, D. B., and NEUSCHEL, V. S., and others) Geophysical abstracts 187, October-December 1961: U. S. Geol. Survey Bull. 1146-D, p. 531-708, 1962.
2-62. (and VITALIANO, D. B., and NEUSCHEL, V. S., and others) Index to Geophysical abstracts 184-187, 1961: U. S. Geol. Survey Bull. 1146-E, p. 709-822, 1962..
3-62. (and VITALIANO, D. B., and NEUSCHEL, V. S., and others) Geophysical abstracts 188, January-March 1962: U. S. Geol. Survey Bull. 1166-A, p. 1-151, 1962.
4-62. (and VITALIANO, D. B., and NEUSCHEL, V. S., and others) Geophysical abstracts 189, April-June 1962: U. S. Geol. Survey Bull. 1166-B, p. 153-315, 1962.
5-62. (and VITALIANO, D. B., and NEUSCHEL, V. S., and others) Geophysical abstracts 190, July-September 1962: U. S. Geol. Survey Bull. 1166-C, p. 317-471, 1962.
6-62. (and VITALIANO, D. B., and NEUSCHEL, V. S., and others) Geophysical abstracts 191, October-December 1962: U. S. Geol. Survey Bull. 1166-D, p. 473-649, 1962.
1-63. (and VITALIANO, D. B., and NEUSCHEL, V. S., and others) Geophysical abstracts: U. S. Geol. Survey Geophys. Abs., no. 192, p. 1-91; no. 193, p. 93-187; no. 194, p. 189-286; no. 195, p. 287-381; no. 196, p. 383-475; no. 197, p. 477-572; no. 198, p. 573-663, 1963.
2-63. (and VITALIANO, D. B., and NEUSCHEL, V. S., and others) Index to Geophysical abstracts 188-191, 1962: U. S. Geol. Survey Bull. 1166-E, p. 651-820, 1963.

CLINE, Denzel R.
1-63. Geology and ground-water resources of Dane County, Wisconsin: U. S. Geol. Survey open-file report, 93 p., 1963.

CLOUD, Preston Ercelle, Jr.
1-62. Behaviour of calcium carbonate in sea water: Geochim. et Cosmochim. Acta, v. 26, p. 867-884, 1962.
2-62. Environment of calcium carbonate deposition west of Andros Island, Bahamas, with sections on Mechanical characteristics of the sediments, by P. D. Blackmon; Microbiology and biochemistry of sediments and overlying water, by F. D. Sisler; Chemical analyses of the water, by Henry Kramer; The problem of calcium determination in sea water, by J. H. Carpenter; Experimental consolidation of calcium carbonate sediment, by E. C. Robertson, L. R. Sykes, and Marcia Newell: U. S. Geol. Survey Prof. Paper 350, 138 p., 1962.

COATS, Robert Roy
1-62. Magma type and crustal structure in the Aleutian arc, in The crust of the Pacific Basin: Am. Geophys. Union Geophys. Mon. 6 (Natl. Acad. Sci.--Natl. Research Council Pub. 1035), p. 92-109, 1962.
2-62. (and BARNETT, P. R., and CONKLIN, N. M.) Distribution of beryllium in unaltered silicic volcanic rocks of the western conterminous United States: Econ. Geology, v. 57, no. 6, p. 963-968, 1962.

COBBAN, William Aubrey
1-62. Baculites from the lower part of the Pierre Shale and equivalent rocks in the Western Interior: Jour. Paleontology, v. 36, no. 4, p. 704-718, 1962.
2-62. Late Cretaceous Desmoscaphites Range Zone in the western interior region: Art. 161 in U. S. Geol. Survey Prof. Paper 450-D, p. D140-D144, 1962.

COFFIN, Donald L.
1-62. Records, logs, and water-level measurements of selected wells and test holes, physical properties of unconsolidated materials, chemical analyses of ground water, and streamflow measurements in the Big Sandy Creek valley in Lincoln, Cheyenne, and Kiowa Counties, Colorado: Colorado Water Conserv. Board [Ground-Water Ser.] Basic-Data Rept. 12, 25 p., 1962. (Prepared by U. S. Geological Survey in coop. with Colorado Water Conservation Board.)

COHEE, George Vincent
1-63. (and PATTON, J. B.) Discussion of the stratigraphic code--Capitalization: Am. Assoc. Petroleum Geologists Bull., v. 47, no. 5, p., 852-853, 1963.

COHEN, Bernard
1-62. (and McCARTHY, L. T., Jr.) Salinity of the Delaware estuary: U. S. Geol. Survey Water-Supply Paper 1586-B, p. B1-B47, 1962.

COHEN, Philip
1-62. Contributions to the hydrology of northern Nevada: Nevada Dept. Conserv. and Nat. Resources Ground-Water Resources--Inf. Ser. Rept. 3, 25 p., 1962. (Prepared in coop. with U. S. Geological Survey.)

COHEN, Philip--Continued
2-62. Preliminary results of hydrogeochemical studies in the Humboldt River Valley near Winnemucca, Nevada: Nevada Dept. Conserv. and Nat. Resources, Water Resources Bull. 19, 27 p., 1962. (Prepared in coop. with U. S. Geological Survey.)
3-62. Source of sulfate in ground water of the Truckee Meadows area, Nevada: Art. 114 in U. S. Geol. Survey Prof. Paper 450-C, p. C131-C132, 1962.
4-62. Stratigraphy and origin of Lake Lahontan deposits of the Humboldt River Valley near Winnemucca, Nevada: Art. 81 in U. S. Geol. Survey Prof. Paper 450-c, p. C63-C65, 1962.
5-62. A preliminary evaluation of the ground-water hydrology of the Valley of the Humboldt River, near Winnemucca, Nevada--A summary; and Specific yield of sediments of the Humboldt River Valley, Humboldt County, Nevada: Nevada Dept. Conserv. and Nat. Resources, Ground-Water Resources--Inf. Ser. Rept. 2, 11 p., 1962. (Prepared by U. S. Geological Survey in coop. with Nevada Dept. of Conservation and Natural Resources.)
1-63. (and LOELTZ, O. J.) Evaluation of hydrogeology and hydrogeochemistry of Truckee Meadows area, Washoe County, Nevada: U. S. Geol. Survey open-file report, 102 p., 1963.

COLBY, Bruce Ronald
1-63. Discussion of "Sediment transportation mechanics--Introduction and properties of sediments," by Task Committee on Preparation of Sedimentation Manual (Am. Soc. Civil Engineers Proc., v. 88, Jour. Hydraulics Div., no. HY 4, pt. 1, p. 77-107, 1962): Am. Soc. Civil Engineers Proc., v. 89, Jour. Hydraulics Div., no. HY 1, pt. 1, p. 266-268, 1963.

COLE, William Storrs
1-63. Tertiary larger Foraminifera from Guam: U. S. Geol. Survey Prof. Paper 403-E, p. E1-E28, 1963.

COLEMAN, Robert Griffin
1-62. Metamorphic aragonite as evidence relating emplacement of ultramafic rocks to thrust faulting in New Zealand [abs.]: Am. Geophys. Union Trans., v. 43, no. 4, p. 447, 1962.
2-62. (and LEE, D. E.) Metamorphic aragonite in the glaucophane schists of Cazadero, California: Am. Jour. Sci., v. 260, no. 8, p. 577-595, 1962.
1-63. Serpentinites, rodingites, and tectonic inclusions in alpine-type mountain chains [abs.]: Geol. Soc. America Spec. Paper 73, p. 130-131, 1963.

COLTON, Roger Burnham
1-63. Geologic map of the Cuskers quadrangle, Roosevelt County, Montana: U. S. Geol. Survey Misc. Geol. Inv. Map I-364, 1963.
2-63. Geologic map of the Hay Creek quadrangle, Roosevelt County, Montana: U. S. Geol. Survey Misc. Geol. Inv. Map I-365, 1963.
3-63. Geologic map of the Spring Creek quadrangle, Valley County, Montana: U. S. Geol. Survey Misc. Geol. Inv. Map I-369, 1963.
4-63. Geologic map of the Tule Valley quadrangle, Roosevelt County, Montana: U. S. Geol. Survey Misc., Geol. Inv. Map I-371, 1963.
5-63. Geologic map of the Porcupine Valley quadrangle, Valley County, Montana: U. S. Geol. Survey Misc. Geol. Inv. Map I-368, 1963.

COMMITTEE on ENVIRONMENTAL STUDIES for PROJECT CHARIOT
1-61. (WOLFE, J. N., chairman, and BRITTON, M. E., and LACHENBRUCH, A. H., and others) Bioenvironmental features of the Ogotoruk Creek area, Cape Thompson, Alaska--A first summary by the Committee on Environmental Studies for Project Chariot: U. S. Atomic Energy Comm. Rept. TID-12439, 69 p., Dec. 1960 (revised, Mar. 1961).
1-62. (WOLFE, J. N., chairman, and BRITTON, M. E., and LACHENBRUCH, A. H., and others) Bioenvironmental features of the Ogotoruk Creek area, Cape Thompson, Alaska--A second summary compiled by the Committee on Environmental Studies for Project Chariot: U. S. Atomic Energy Comm. Rept. TID-17226, 183 p., 1962.

CONNOR, Jon J.
1-63. Geology of the Angostura Reservoir quadrangle, Fall River County, South Dakota: U. S. Geol. Survey Bull. 1063-D, p. 85-126, 1963.

CONOVER, William J.
1-63. (and BENSON, M. A.) Long-term flood frequencies based on extremes of short-term records: Art. 228 in U. S. Geol. Survey Prof. Paper 450-E, p. E159-E160, 1963.

COOPER, Gustav Arthur
1-62. (and GRANT, R. E.) Torynechus, new name for Permian brachiopod Uncinuloides King: Jour. Paleontology, v. 36, no. 5, p. 1128-1129, 1962.

COOPER, Hilton Hammond, Jr.
1-63. (and RORABAUGH, M. I.) Ground-water movements and bank storage due to flood stages in surface streams: U. S. Geol. Survey open-file report, 47 p., 1963.

COOPER, James Blair
1-62. Ground water: U. S. Atomic Energy Comm. Rept. PNE-130F, p. 112-137, 1962. (Report prepared for U. S. Atomic Energy Commission by U. S. Geological Survey for Project Gnome.)
1-63. Ground water in Cenozoic fill in collapse structures, southeastern Eddy County, New Mexico: Art. 225 in U. S. Geol. Survey Prof. Paper 450-E, p. E152-E153, 1963.

CORNWALL, Henry Rowland
1-62. Calderas and associated volcanic rocks near Beatty, Nye County, Nevada, in Petrologic studies--A volume in honor of A. F. Buddington: New York, New York, Geol. Soc. America, p. 357-371, 1962.

CORWIN, Gilbert
1-62. Results of 1962 nationwide geology examination offered by United States Civil Service Commission: Am. Assoc. Petroleum Geologists Bull., v., 46, no. 9, p. 1745-1746, 1962.

COULTER, Henry Welty
1-62. (and COULTER, E. B.) Preliminary geologic map of the Valdez-Tiekel belt, Alaska: U. S. Geol. Survey Misc. Geol. Inv. Map I-356, 1962.

COUNTS, Harlan B.
1-62. Ground Water Branch, in Geological investigations in Georgia, 1962: Georgia Mineral Newsletter, v. 15, nos. 3-4, p. 42-43, 1962.

COX, Allan V.
1-62. (and DOELL, R. R.) Magnetic properties of the basalt in hole EM 7, Mohole project: Jour. Geophys. Research, v. 67, no. 10, p. 3997-4004, 1962.
2-62. (and DOELL, R. R.) Paleomagnetic evidence from the Island of Hawaii for long-period secular variation [abs.]: Am. Geophys. Union Trans., v.,43, no. 4, p. 438, 1962.
3-62. Analysis of present geomagnetic field for comparison with paleomagnetic results: Jour. Geomagnetism and Geoelectricity (Kyoto, Japan), v. 8, nos. 3-4, p. 101-112, 1962.
1-63. Angular dispersion due to random vectors [abs.]: Am. Geophys. Union Trans., v. 44, no. 1, p. 33, 1963.
2-63. (and DOELL, R. R.) Analysis of partial alternating field demagnetization apparatus [abs.]: Am. Geophys. Union Trans., v. 44, no. 1, p. 33, 1963.
3-63. (and DOELL, R. R., and DALRYMPLE, G. B.) Geomagnetic polarity epochs and Pleistocene geochronometry: Nature (London), v. 198, no. 4885, p. 1049-1051, 1963.

COX, Dennis Purver
1-63. Structural geology of the Serra de Jacobina, Bahía, Brazil [abs.]: Geol. Soc. America Spec. Paper 73, p. 133, 1963.

COX, Edward R.
1-62. (and KUNKLER, J. L.) Feasibility of injecting brine from Malaga Bend into the Delaware Mountain Group, Eddy County, New Mexico: U. S. Geol. Survey open-file report, 71 p., 1962.
1-63. Effects of three irrigation wells on the flow of Rattlesnake Springs, Eddy County, New Mexico, February 1, 1961 to February 1, 1962: U. S. Geol. Survey open-file report, 37 p., 1963.

CRANDELL, Dwight Raymond
1-62. (and MULLINEAUX, D. R., and MILLER, R. D., and RUBIN, Meyer) Pyroclastic deposits of Recent age at Mount Rainier, Washington: Art. 138 in U. S. Geol. Survey Prof. Paper 450-D, p. D64-D68, 1962.
1-63. Glaciation of the southwestern Olympic Peninsula, Washington [abs.]: Geol. Soc. America Spec. Paper 73, p. 32, 1963.

CREASEY, Saville Cyrus
1-62. (and KISTLER, R. W.) Age of some copper-bearing porphyries and other igneous rocks in southeastern Arizona: Art. 120 in U. S. Geol. Survey Prof. Paper 450-D, p. D1-D5, 1962.

CRESSMAN, Earle R.
1-62. Nondetrital siliceous sediments, Chap.,T in Fleischer, Michael, ed., Data of geochemistry, 6th edition: U. S. Geol. Survey Prof. Paper 440-T, p. T1-T23, 1962.

CRIDLAND, Arthur A.
1-62. (and SCHOPF, J. M.) Plant fossils five degrees from the South Pole [abs.]: Am. Jour. Botany, v. 49, no. 6, pt. 2, p. 669, 1962.

CRINER, James H.
1-63. (and SUN, P.-C. P., and NYMAN, D. J.) Hydrology of aquifer systems in the Memphis area, Tennessee: U. S. Geol. Survey open-file report, 94 p., 1963.

CRITTENDEN, Max Dermont, Jr.
1-62. (and CUTTITTA, Frank, and ROSE, H. J., Jr., and FLEISCHER, Michael) Studies on manganese oxide minerals--VI, Thallium in some manganese oxides: Am. Mineralogist, v. 47, nos. 11-12, p. 1461-1467, 1962.
1-63. Effective viscosity of the earth derived from isostatic loading of Pleistocene Lake Bonneville, Utah [abs.]: Am. Geophys. Union Trans., v. 44, no. 1, p. 104, 1963.
2-63. Tectonic evolution of the Wasatch-Great Basin border--Traverse Range to Brigham City, Utah [abs.]: Geol. Soc. America Spec. Paper 73, p. 81, 1963.

CRONIN, James Gerald
1-62. (and FOLLETT, C. R., and SHAFER, G. H., and RETTMAN, P. L.) A reconnaissance of the ground-water resources of the Brazos River basin, Texas: U. S. Geol. Survey open-file report, 228 p., 1962.
1-63. (and WELLS, L. C.) Geology and ground-water resources of Hale County, Texas: U. S. Geol. Survey Water-Supply Paper 1539-U, p. U1-U38, 1963.

CROSTHWAITE, Emerson Gerald
1-62. Ground-water reconnaissance in Round Valley, Custer County, Idaho: U. S. Geol. Survey open-file report, 27 p., 1962.
2-62. Ground-water reconnaissance of the Sailor Creek area, Owyhee, Elmore, and Twin Falls Counties, Idaho: U. S. Geol. Survey open-file report, 59 p., 1962.

CULBERTSON, William Craven
1-62. Laney Shale Member and Tower Sandstone Lentil of the Green River Formation, Green River area, Wyoming: Art. 78 in U. S. Geol. Survey Prof. Paper 450-C, p. C54-C57, 1962.
1-63. Correlation of the Parkwood Formation and the lower members of the Pottsville Formation in Alabama: Art. 193 in U. S. Geol. Survey Prof. Paper 450-E, p. E47-E50, 1963.
2-63. Pennsylvanian nomenclature in northwest Georgia: Art. 194 in U. S. Geol. Survey Prof. Paper 450-E, p. E51-E57, 1963.

CUMMINGS, David
1-63. Stratigraphy and structure of the Bays Mountain synclinorium, northeast Tennessee [abs.]: Geol. Soc. America Spec.,Paper 73, p. 133-134, 1963.

CUPPELS, Norman Paul
1-62. Description, composition, and tenor of unconsolidated sediments in monazite-bearing tributaries to the Enoree, Tyger, and Pacolet Rivers in the western Piedmont of South Carolina: U. S. Geol. Survey open-file report, 17 p., 1962.

CUSHING, Elliot Morse
1-63. Water resources and the Mississippi embayment project: U. S. Geol. Survey Circ. 471, 8 p., 1963.

CUTTITTA, Frank
1-62. (and CARRON, M. K., and FLETCHER, J. D., and CHAO, E. C.-T.) Chemical composition of bediasites and philippinites, in Astrogeologic studies--Semiannual progress report, Feb.,26, 1961 to Aug. 24, 1961: U. S. Geol. Survey open-ile report, p. 15-47, 1962.
2-62. (and CARRON, M.,K., and CHAO, E. C.-T.) New chemical data on Texas tektites, 1, Major elements [abs.]: Jour. Geophys. Research, v. 67, no. 9, p. 3552, 1962.
1-63. (and CHAO, E. C.-T., and ANNELL, C. S., and CARRON, M. K., and FLETCHER, J. D.) The alkali content of Texas tektites [abs.]: Am. Geophys. Union Trans., v. 44, no. 1, p. 93, 1963.
2-63. (and CARRON, M. K., and FLETCHER, J. D., and ANNELL, C. S., and CHAO, E. C.-T.) The chemical composition of bediasites, in Astrogeologic studies--Annual progress report, Aug. 25, 1961 to Aug. 24, 1962, Pt. C, Cosmochemistry and petrography: U. S. Geol. Survey open-file report, p. 115-129, 1963.

CZAMANSKE, Gerald K.
1-63. (and ROEDDER, E. W., and BURNS, F. C.) Neutron activation analysis of fluid inclusions for copper, manganese, and zinc: Science, v. 140, no. 3565, p. 401-403, 1963.

DANIELS, Raymond Bryant
1-63. (and RUBIN, Meyer, and SIMONSON, G. H.) Alluvial chronology of the Thompson Creek Watershed, Harrison County, Iowa: Am. Jour. Sci., v. 261, no. 5, p. 473-487, 1963.

DANILCHIK, Walter
1-62. (and ARNDT, H. H., and WOOD, G. H., Jr.) Geology of anthracite in the eastern part of the Shamokin quadrangle, Northumberland County, Pennsylvania: U. S. Geol. Survey Coal Inv. Map C-46, 2 sheets, 1962.

DAVIDSON, David Francis
1-62. (and LAKIN, H. W.) Metal content of some black shales of the Western Conterminous United States--Part 2: Art. 85 in U. S. Geol. Survey Prof. Paper 450-C, p. C74, 1962.
1-63. Selenium in some oxidized sandstone-type uranium deposits: U. S. Geol. Survey Bull. 1162-C, p. C1-C33, 1963.

DAVIES, William Edward
1-62. Geology and other natural features of Centrum Sø area, in Needleman, S. M., ed., Arctic earth science investigations, Centrum Sø, Northeast Greenland, 1960: U. S. Air Force Cambridge Research Labs. Geophysics Research Directorate Air Force Surveys Geophysics, no. 138 (AFCRL-62-695), p. 5-12, 1962.
2-62. (and KRINSLEY, D. B.) The recent regimen of the ice cap margin in North Greenland, in Symposium of Obergurgl, Sept. 1962: Internat. Assoc. Sci. Hydrology (Gentbrugge, Belgium) Pub. 58, p. 119-130, 1962.
1-63. Attapulgite from Carlsbad Caverns, New Mexico [abs.]: D. C. Speleograph, v. 19, no. 5, supp., p. 3, 1963.

DAVIS, Carol Waite
1-63. (and MIESCH, A. T., and EICHER, R. N., and MORRIS, E. C.) Computer analysis of microphotometer data from lunar photographs, in Astrogeologic studies--Annual progress report, Aug. 25, 1961 to Aug. 24, 1962, Pt. A, Lunar and planetary investigations: U. S. Geol. Survey open-file report, p. 32-50, 1963.

DAVIS, Daniel Arthur
1-63. (and YAMANAGA, George) Preliminary report on the water resources of Kohala Mountain and Mauna Kea, Hawaii: U. S. Geol. Survey open-file report, 88 p., 1963.

DAVIS, George Hamilton
1-62. Erosional features of snow avalanches, Middle Fork Kings River, California: Art. 155 in U. S. Geol. Survey Prof. Paper 450-D, p. D122-D125, 1962.
2-62. (and GREEN, J. H.) Structural control of interior drainage, southern San Joaquin Valley, California: Art. 146 in U. S. Geol. Survey Prof. Paper 450-D, p. D89-D91, 1962.

DAVIS, Gordon E.
1-63. (and HARDT, W. F., and THOMPSON. L. K., and COOLEY, M. E.) Geohydrologic data in the Navajo and Hopi Indian Reservations, Arizona, New Mexico, and Utah--Pt. 1, Records of ground-water supplies: Arizona State Land Dept., Water Resources Rept. 12-A, 159 p., 1963. (Prepared by U. S. Geological Survey in coop. with Bureau of Indian Affairs.)
2-63. (and HARDT, W. F., and THOMPSON, L. K., and COOLEY, M. E.) Geohydrologic data in the Navajo and Hopi Indian Reservations, Arizona, New Mexico, and Utah--Pt. 1, Records of ground-water supplies: U. S. Geol. Survey open-file report, 5 p., 1963.

DAVIS, Marvin E.
1-62. (and LEGGAT, E. R.) Reconnaissance of the ground-water resources of the upper Rio Grande basin in Texas: U. S. Geol. Survey open-file report, 145 p., 1962.

DAVIS, Robert Ellis
1-62. (and IZETT, G. A.) Geology and uranium deposits of the Strawberry Hill quadrangle, Crook County, Wyoming: U. S. Geol. Survey Bull. 1127, 87 p., 1962 [1963].

DeCOOK, Kenneth James
1-63. Geology and ground-water resources of Hays County, Texas: U. S. Geol. Survey Water-Supply Paper 1612, 72 p., 1963.

DEMPSEY, William Joseph
1-62. (and STUART, D. J., and others) Aeromagnetic map of south central Fremont County, Wyoming: U. S. Geol. Survey Geophys. Inv. Map GP-393, 1962.

DEMPSEY, William Joseph--Continued
1-63. (and LONG, C. L., and others) Aeromagnetic map of parts of southern Mora, northern San Miguel, and western Harding Counties, New Mexico: U. S. Geol. Survey Geophys. Inv. Map GP-356, 1963.
2-63. (and PAGE, E. E., and others) Aeromagnetic map of parts of southern Colfax, northern Mora, and western Harding Counties, New Mexico: U. S. Geol. Survey Geophys. Inv. Map GP-355, 1963.
3-63. (and PETRAFESO, F. A., and others) Aeromagnetic map of the central part of San Miguel County, New Mexico: U. S. Geol. Survey Geophys. Inv. Map GP-357, 1963.
4-63. (and FACKLER, W. D., and others) Aeromagnetic map of the Dragoon quadrangle, Cochise County, Arizona: U. S. Geol. Survey Geophys. Inv. Map GP-412, 1963.
5-63. (and HILL, M. E.) Aeromagnetic map of parts of the Phoenix, Mesa, Camelback, and New River SE quadrangles, Maricopa County, Arizona: U. S. Geol. Survey Geophys.,Inv. Map GP-420, 1963.
6-63. (and HILL, M. E.) Aeromagnetic map of parts of the Willcox and Luzena quadrangles, Cochise County, Arizona: U. S. Geol. Survey Geophys. Inv. Map GP-418, 1963.
7-63. (and STUART, D. J., and others) Aeromagnetic map of the northeastern part of the Wind River Indian Reservation, Wyoming: U. S. Geol. Survey Geophys. Inv. Map GP-400, 1963.
8-63. (and HILL, M. E., and others) Aeromagnetic map of central Yavapai County, Arizona, including the Jerome mining district: U. S. Geol. Survey Geophys. Inv. Map GP-402, 1963.
9-63. Aeromagnetic map of Melbourne and vicinity, Brevard County, Florida: U. S. Geol. Survey Geophys. Inv. Map GP-425, 1963.

DEVAUL, Robert W.
1-62. (and MAXWELL, B. W.) Availability of ground water in Daviess and Hancock Counties, Kentucky--Sheet 1, Geologic map; sheet 2, Ground water; sheet 3, Generalized columnar section: U. S. Geol. Survey Hydrol. Inv. Atlas HA-27, 1962.
2-62. (and MAXWELL, B. W.) Availability of ground water in McLean and Muhlenberg Counties, Kentucky--Sheet 1, Geologic map; sheet 2, Ground water; sheet 3, Generalized columnar section: U. S. Geol. Survey Hydrol. Inv. Atlas HA-29, 1962.

DIAZ, Arthur M.
1-63. Dissolved-salt contribution to Great Salt Lake, Utah: Art. 230 in U. S. Geol. Survey Prof. Paper 450-E, p. E163-E165, 1963.

DIBBLEE, Thomas Wilson, Jr.
1-62. Displacements on the San Andreas rift zone and related structures in Carrizo Plain and vicinity, in San Joaquin Geol. Soc., Guidebook--Geology of Carrizo Plains and San Andreas Fault, p. 5-12, 1962.
1-63. Structure of eastern San Gabriel Mountains and Cajon Pass area, southern California [abs.]: Geol. Soc. America Spec. Paper 73, p. 33, 1963.
2-63. Geology of the Willow Springs and Rosamond quadrangles, California: U. S. Geol. Survey Bull. 1089-C, p.,141-253, 1963.

DICKEY, Dayton Delbert
1-62. (and EMERICK, W. L.) Interim geological investigations in the U12b.09 and U12b.07 tunnels, Nevada Test Site, Nye County, Nevada, with a section on Gamma-radioactivity, by C. M. Bunker: U. S. Geol. Survey Rept. TEI-797 (open-file report), 21 p., 1962. (Report prepared for U. S. Atomic Energy Commission.)
2-62. (and GARD, L. M., Jr.) Physical properties [of the rocks]: U. S. Atomic Energy Comm. Rept. PNE-130F, p. 49-53, 1962. (Report prepared for U. S. Atomic Energy Commission by U. S. Geological Survey for Project Gnome.)

DIMENT, William Horace
1-63. A heat flow determination from a drill hole near Oak Ridge, Tennessee [abs.]: Am. Geophys. Union Trans., v. 44, no. 1, p. 105, 1963.

DINGMAN, Robert J.
1-62. Tertiary salt domes near San Pedro de Atacama, Chile: Art. 147 in U. S. Geol. Survey Prof. Paper 450-D, p. D92-D94, 1962.
1-63. Formation of "salt cups" near San Pedro de Atacama, Chile: Art. 207 in U. S. Geol. Survey Prof. Paper 450-E, p. E103-E104, 1963.
2-63. Reversal of throw along a line of low-angle thrust faulting near San Pedro de Atacama, Chile: Art. 186 in U. S. Geol. Survey Prof. Paper 450-E, p. E25-E27, 1963.

DINWIDDIE, George A.
1-63. Municipal and community water supplies in southeastern New Mexico: U. S. Geol. Survey open-file report, 263 p., 1963.

DIXON, H. Roberta
1-63. (and LUNDGREN, L. W., Jr., and SNYDER, G. L., and EATON, G. P.) Colchester nappe of eastern Connecticut [abs.]: Geol. Soc. America Spec. Paper 73, p. 139, 1963.

DOBROVOLNY, Ernest
1-62. Geologfa del valle de La Paz: Bolivia Dept. Nac. Geologfa, La Paz, Bol. 3 (espec.), 152 p., 1962.
1-63. Preliminary geologic map of part of the Rapid City East quadrangle, South Dakota: U. S. Geol. Survey open-file report, 1963.

DODSON, Chester L.
1-63. Relationship of rocks in the Great Smoky Group to rocks in the Murphy Marble belt, western North Carolina [abs.]: Geol.,Soc. America, Southeastern Sec., Ann. Mtg., Roanoke, Virginia, Apr. 1963, Program, p. 20, 1963.
2-63. (and MILLER, J. A.) Contrasting varieties of hornblende gneiss in Clay County, North Carolina [abs.]: Geol. Soc. America, Southeastern Sec., Ann. Mtg., Roanoke, Virginia, Apr. 1963, Program, p. 20, 1963.

DOE, Bruce R.
1-62. Distribution and composition of sulfide minerals at Balmat, New York: Geol. Soc. America Bull., v. 73, no. 7, p. 833-854, 1962.
2-62. Interrelationships of lead, uranium, and thorium among volcanic glasses of the western United States [abs.]: Am. Geophys. Union Trans., v. 43, no. 4, p. 449, 1962.

DOE, Bruce R.--Continued
3-62. (and TILTON, G. R.) Isotopic composition of lead in potassium feldspars from the Appalachian province in Maryland and Virginia [abs.]: Jour. Geophys. Research, v. 67, no. 9, p. 3553-3554, 1962.
1-63. (and HART, S. R.) The effect of contact metamorphism on lead in potassium feldspars near the Eldora stock, Colorado: Jour. Geophys. Research, v. 68, no. 11, p. 3521-3530, 1963..

DOELL, Richard Rayman
1-62. (and COX, A. V.) Determination of the magnetic polarity of rock samples in the field: Art. 151 in U. S. Geol. Survey Prof. Paper 450-D, p. D105-D108, 1962.
2-62. (and COX, A. V., and KISTLER, R. W., and DALRYMPLE, G. B.) Radiometric ages of Pleistocene reversal zones from igneous rocks in California [abs.]: Am. Geophys. Union Trans., v. 43, no. 4, p. 438, 1962.
1-63. (and COX, A. V.) The accuracy of the paleomagnetic method as evaluated from historic Hawaiian lava flows: Jour. Geophys. Research, v.68, no. 7, p. 1997-2009, 1963.
2-63. Seismic depth study of the Salmon Glacier, British Columbia: Jour. Glaciology (Cambridge, England), v. 4, no. 34, p. 425-437, 1963.

DOLL, Charles George
1-63. (and CADY, W. M., and THOMPSON, J. B., Jr., and BILLINGS, M. P.) Reply to Zen's discussion of the Centennial Geologic Map of Vermont: Am. Jour. Sci., v. 261, no. 1, p. 94-96, 1963.

DONNELL, John Roswell
1-62. Geology and coal resources of the Carbondale area, Garfield, Pitkin and Gunnison Counties, Colorado: U. S. Geol. Survey open-file report, 1 map, 1962.

DREWES, Harald Dietrich
1-63. Paleozoic types and rates of deposition in the eastern Great Basin [abs.]: Geol. Soc. America Spec. Paper 73, p. 83, 1963.
2-63. Geology of the Funeral Peak quadrangle, California, on the east flank of Death Valley: U. S. Geol. Survey Prof. Paper 413, 78 p., 1963.

DUNKLE, David Hosbrook
1-63. (and TEICHERT, Curt and HABIB-UR-RAHMAN) Stratigraphic research as applied to mineral resources exploration and development in Pakistan, in U. S. Dept. State, Natural resources--Minerals and mining, mapping and geodetic control: United Nations Conf. Application Sci. and Technology Benefit Less Developed Areas, Geneva, 1963, U. S. Papers, v. 2, p. 173-182, 1963.

DURFOR, Charles N.
1-63. (and ANDERSON, Peter W.) Chemical quality of surface waters in Pennsylvania: U. S. Geol. Survey Water-Supply Paper 1619-W, p. W1-W50, 1963.
2-63. Water requirements of the styrene, butadiene and synthetic-rubber industries: U. S. Geol. Survey Water-Supply Paper 1330-F, p. 221-285, 1963.

DURUM, Walton Henry
1-63. (and HAFFTY, Joseph) Implications of the minor element content of some major streams of the world: Geochim. et Cosmochim. Acta, v. 27, no. 1, p. 1-11, 1963.

DURY, George Harry
1-62. Results of seismic exploration of meandering valleys: Am. Jour. Sci., v. 260, no. 9, p. 691-706, 1962.

DUTCHER, Lee C.
1-62. (and BADER, J. S., and HILTGEN, W. J.) Data on wells in the Edwards Air Force Base area, California: California Dept. Water Resources Bull. 91-6, 209 p., 1962. (Prepared by U. S. Geological Survey.)
1-63. (and BADER, J. S.) Geology and hydrology of Agua Caliente Spring, Palm Springs, California: U. S. Geol. Survey Water-Supply Paper 1605, 41 p., 1963.

DUTTON, Carl Evans
1-62. Geologic formation--Bedrock, in Hole, F. D., and others, Soil survey of Florence County, Wisconsin: Wisconsin Geol. and Nat. History Survey Bull. 84 (Soil Ser., no. 59), p. 40-41, 1962.

DYER, Henry Bennett
1-63. (and BADER, J. S., and GIESSNER, F. W., and others) Data on water wells and springs in the lower Mojave Valley area, San Bernardino County, California: U. S. Geol. Survey open-file report, 37 p., 1963.

EAKIN, Thomas Emory
1-62. Ground-water appraisal of Cave Valley in Lincoln and White Pine Counties, Nevada: Nevada Dept. Conserv. and Nat. Resources, Ground-Water Resources--Reconn. Ser. Rept. 13, 18 p., 1962. (Prepared by U. S. Geological Survey in coop. with Nevada Dept. Conservation and Natural Resources.)
2-62. Ground-water appraisal of Ralston and Stonecabin Valleys, Nye County, Nevada: Nevada Dept. Conserv. and Nat. Resources Ground-Water Resources--Reconn. Ser. Rept. 12, 31 p., 1962. (Prepared by U. S. Geological Survey in coop. with Nevada Dept. Conservation and Natural Resources.)

EARGLE, Dolan Hoye
1-62. Problems of nomenclature in the stratigraphy of southern Mississippi [abs.]: Gulf Coast Assoc. Geol. Socs. Trans., v. 12, p. 156, 1962.
2-62. (and FOUST, R. T., Jr.) Tertiary stratigraphy and uranium mines of the southeast Texas Coastal Plain, Houston to San Antonio, via Goliad, Field excursion no. 4, November 15, 1962, in Geol. Soc. America, Geology of the Gulf Coast and central Texas and guidebook of excursions: Houston, Texas, Houston Geol. Soc., p. 225-253, 1962.
3-62. (and WEEKS, A. D.) Geologic setting and origin of the uranium deposits of the Karnes area, southeast Texas [abs.]: Econ. Geology, v. 57, no. 6, p. 1010, 1962; abs., Geol. Soc. America Spec. Paper 73, p. 142, 1963.

EARGLE, Dolan Hoye--Continued

1-63. Stratigraphy and structural relations of Tatum salt dome area, southeastern Mississippi [abs.]: Geol. Soc. America Spec. Paper 73, p. 273, 1963.

EATON, Jerry Paul

1-62. Crustal structure and volcanism in Hawaii, in The crust of the Pacific Basin: Am. Geophys. Union Geophys. Mon. 6 (Natl. Acad. Sci.--Natl. Research Council Pub. 1035), p. 13-29, 1962.

2-62. (and MURATA, K.,J.) How volcanoes grow, in White, J. F., ed., Study of the Earth--Readings in geological science: Englewood Cliffs, New Jersey, Prentice-Hall, Inc., p. 137-164, 1962.

1-63. Earthquakes of the 1959-1960 eruption of Kilauea [abs.]: Geol. Soc. America Spec. Paper 73, p. 37-38, 1963.

EDELEN, George W., Jr.

1-63. (and CROSS, W. P., and SOMERS, W. P.) Floods on Crab Creek at Youngstown, Ohio: U. S. Geol. Survey Hydrol. Inv. Atlas HA-56, 1963. (Prepared in coop. with Ohio Dept. Natural Resources.)

2-63. (and RUGGLES, F. H., Jr., and CROSS, W. P.) Floods at Warren, Ohio: U. S. Geol. Survey Hydrol. Inv. Atlas HA-51, 1963. (Prepared in coop. with Ohio Dept. Natural Resources.)

EGGLETON, Richard Elton

1-62. (and MARSHALL, C. H.) Notes on the Apenninian Series and pre-Imbrian stratigraphy in the vicinity of Mare Humorum and Mare Nubium, in Astrogeologic studies--Semiannual progress report, Feb. 26, 1961 to Aug. 24, 1961: U. S. Geol. Survey open-file report, p. 132-137, 1962.

2-62. (and MARSHALL, C. H.) Pre-Imbrian history of the lunar surface [abs.]: Am. Geophys. Union Trans., v. 43, no. 4, p. 464, 1962.

1-63. Thickness of the Apenninian Series in the Lansberg region of the Moon, in Astrogeologic studies--Annual progress report, Aug. 25, 1961 to Aug. 24, 1962, Pt. A, Lunar and planetary investigations: U. S. Geol. Survey open-file report, p. 19-31, 1963.

EISENLOHR, William Stewart, Jr.

1-62. Use of short records of runoff to estimate a 25-year average runoff in the Potomac River basin: Art. 173 in U. S. Geol. Survey Prof. Paper 450-D, p. D178-D179, 1962.

2-62. (and others) Exploration for water supplies on the public domain, 1960: U. S. Geol. Survey Circ. 461, 28 p., 1962.

ELBERG, Edward L., Jr.

1-63. (and GIERHART, R. D., and RAMIREZ, L. F.) Geology of the eastern Rub al Khali quadrangle, Kingdom of Saudi Arabia: U. S. Geol. Survey Misc. Geol. Inv. Map I-215 A, 1963.

ELLIS, Davis W.

1-62. (and ALLEN, H. E., and NOEHRE, A. W.) Floods in Aurora North quadrangle, Illinois: U. S. Geol. Survey open-file report, 7 p., 1962.

2-62. (and ALLEN, H. E., and NOEHRE, A. W.) Floods in Elmhurst quadrangle, Illinois: U. S. Geol. Survey open-file report, 8 p., 1962.

3-62. (and ALLEN, H. E., and NOEHRE, A. W.) Floods in Highland Park quadrangle, Illinois: U. S. Geol. Survey open-file report, 9 p., 1962.

4-62. (and ALLEN, H. E., and NOEHRE, A. W.) Floods in Wheeling quadrangle, Illinois: U. S. Geol. Survey open-file report, 9 p., 1962.

1-63. (and ALLEN, H. E., and NOEHRE, A. W.) Floods in Arlington Heights quadrangle, Illinois: U. S. Geol. Survey Hydrol. Inv. Atlas HA-67, 1963. (Prepared in coop.,with Northeastern Illinois Metropolitan Area Planning Commission.)

2-63. (and ALLEN, H. E., and NOEHRE, A. W.) Floods in Elmhurst quadrangle, Illinois: U. S. Geol. Survey Hydrol. Inv. Atlas HA-68, 1963.

ELSTON, Donald Parker

1-62. (and SHOEMAKER, E. M., and LANDIS, E. R.) Uncompahgre front and salt anticline region of Paradox basin, Colorado and Utah: Am. Assoc. Petroleum Geologists Bull., v. 46, no. 10, p. 1857-1878, 1962.

1-63. (and SHOEMAKER, E. M.) Salt anticlines of the Paradox basin, Colorado and Utah: Northern Ohio Geol. Soc., Symposium on Salt, Cleveland, May 1962, p. 131-146, 1963.

EMERICK, William L.

1-62. (and DICKEY, D. D., and McKEOWN, F. A.) Interim geological investigations in the U12e.04 tunnel, Nevada Test Site, Nye County, Nevada: U. S. Geol. Survey Rept. TEI-776, open-file report, 27 p., 1962. (Report prepared for U. S. Atomic Energy Commission.)

2-62. (and HOUSER, F. N.) Interim geological investigations in the U12b.08 tunnel, Nevada Test Site, Nye County, Nevada: U. S. Geol. Survey Rept. TEI-814, open-file report, 23 p., 1962. (Report prepared for U. S. Atomic Energy Commission.)

EMERY, Kenneth Orris

1-62. Marine geology of Guam: U. S. Geol. Survey Prof. Paper 403-B, p. B1-B76, 1962.

EMERY, Philip A.

1-63. (and MALHOIT, M. M.) Water levels in observation wells in Nebraska, 1962: U. S. Geol. Survey open-file report, 2 p., 1963.

2-63. (and MALHOIT, M. M.) Water levels in observation wells in Nebraska, 1962: Nebraska Univ. Conserv. and Survey Div., Nebraska Water-Survey Paper 13, 157 p., 1963. (Prepared by U. S. Geological Survey in coop. with the Conservation and Survey Division, University of Nebraska.)

ENGEL, Albert Edwin John

1-62. (and ENGEL, C. G.) Hornblendes formed during progressive metamorphism of amphibolites, northwest Adirondack Mountains, New York: Geol. Soc. America Bull., v. 73, no. 12, p. 1499-1514, 1962.

2-62. (and JAMES, H. L., and LEONARD, B. F., 3d, eds.) Petrologic studies--A volume in honor of A. F. Buddington: New York, New York, Geol. Soc. America, 660 p., 1962.

3-62. (and ENGEL, C. G.) Progressive metamorphism of amphibolite, northwest Adirondack Mountains, New York, in Petrologic studies--A volume in honor of A. F. Buddington: New York, New York, Geol. Soc. America, p. 37-82, 1962.

1-63. (and ENGEL, C. G.) Metasomatic origin of large parts of the Adirondack phacoliths: Geol. Soc. America Bull., v. 74, no. 3, p. 349-352, 1963.

ENGEL, Celeste G.

1-63. (and ENGEL, A. E. J.) Basalts dredged from the northeastern Pacific Ocean: Science, v. 140, no. 3573, p. 1321-1324, 1963.

ENGLUND, Kenneth John

1-63. (and SMITH, H. L., and HARRIS, L. D., and STEPHENS, J. G.) Geology of the Ewing quadrangle, Kentucky and Virginia: U. S. Geol. Survey Bull. 1142-B, p. B1-B23, 1963.

2-63. (and LANDIS, E. R., and SMITH, H. L.) Geology of the Varilla quadrangle, Kentucky-Virginia: U. S. Geol. Survey Geol. Quad. Map GQ-190, 1963.

3-63. (and ROEN, J. B.) Origin of the Middlesboro Basin, Kentucky: Art. 184 in U. S. Geol. Survey Prof. Paper 450-E, p. E20-E22, 1963.

ERICKSEN, George Edward

1-63. (and RUIZ FULLER, Carlos, and PIZARRO A., Bernardo) Development, organization, and operation of the Instituto de Investigaciones Geológicas of Chile, in U. S. Dept. State, Natural resources--Minerals and mining, mapping and geodetic control: United Nations Conf. Application Sci. and Technology Benefit Less Developed Areas, Geneva, 1963, U. S. Papers, v. 2, p. 45-52, 1963.

ERICKSON, Ralph LeRoy

1-63. (and BLADE, L. V.) Geochemistry and petrology of the alkalic igneous complex at Magnet Cove, Arkansas: U. S. Geol. Survey Prof. Paper 425, 95 p., 1963.

ESPENSHADE, Gilbert Howry

1-61. Resources, Chap. 3 in Klinefelter, T. A., and Cooper, J. D., Kyanite--A materials survey: U. S. Bur. Mines Inf. Circ. 8040, p. 8-19, 1961 [1962].

1-63. Geology of some copper deposits in North Carolina, Virginia, and Alabama: U. S. Geol. Survey open-file report, p. 29-82, 1963.

2-63. (and SPENCER, C. W.) Geology of phosphate deposits of northern peninsular Florida: U. S. Geol. Survey Bull. 1118, 115 p., 1963.

ESPEY, William H., Jr.

1-62. Discussion of "Unit hydrograph characteristics for sewered areas," by P. S. Eagleson (Am. Soc. Civil Engineers Proc., v. 88, Jour. Hydraulics Div., no. HY 2, pt. 1, p. 1-25, 1962): Am. Soc. Civil Engineers Proc., v. 88, Jour. Hydraulics Div., no. HY 6, pt. 1, p. 181-184, 1962.

2-62. (and SAUER, S. P.) Discussion of "Hydrologic design of culverts," by V. T. Chow (Am. Soc. Civil Engineers Proc., v. 88, Jour. Hydraulics Div., no. HY 2, pt. 1, p. 39-55, 1962): Am. Soc. Civil Engineers Proc., v. 88, Jour. Hydraulics Div., no. HY 6, pt. 1, p. 191-192, 1962.

EUGSTER, Hans Peter

1-62. (and PROSTKA, H. J., and APPLEMAN, D. E.) Unit-cell dimensions of natural and synthetic scapolites: Science, v. 137, no. 3533, p. 853-854, 1962.

1-63. (and PROSTKA, H. J., and APPLEMAN, D. E.) Cell dimensions of natural and synthetic scapolites [abs.]: Geol. Soc. America Spec. Paper 73, p. 146-147, 1963.

EVANS, Howard Tasker, Jr.

1-63. (and BERNER, R. A., and MILTON, Charles) Valleriite and mackinawite [abs.]: Geol. Soc. America Spec. Paper 73, p. 147, 1963.

EVENSON, Robert Edward

1-62. Ground-water conditions, U. S. Naval Missile Facility, Point Arguello, California, June 1961-June 1962: U. S. Geol. Survey open-file report, 20 p., 1962.

2-62. (and WILSON, H. D., Jr., and MUIR, K. S.) Yield of the Carpinteria and Goleta ground-water basins, Santa Barbara County, California, 1941-58: U. S. Geol. Survey open-file report, 137 p., 1962.

1-63. (and MILLER, G. A.) Geology and ground-water features of Point Arguello Naval Missile Facility, Santa Barbara County, California: U. S. Geol. Survey Water-Supply Paper 1619-F, p., F1-F35, 1963.

FADER, Stuart Wesley

1-63. Hydrology of Grant and Stanton Counties, Kansas [abs.]: Geol. Soc. America Spec. Paper 73, p. 148-149, 1963.

FAHEY, Joseph John

1-63. (and YORKS, K. P.) Wegscheiderite ($Na_2CO_3 \cdot 3NaHCO_3$), a new saline mineral from the Green River Formation, Wyoming: Am. Mineralogist, v. 48, nos. 3-4, p. 400-403, 1963.

2-63. Separation of coesite and stishovite [abs.]: Geol. Soc. America Spec. Paper 73, p. 149, 1963.

FAHNESTOCK, Robert Kendall

1-62. (and HAUSHILD, W. L.) Flume studies of the transport of pebbles and cobbles on a sand bed: Geol. Soc. America Bull., v. 73, no. 11, p. 1431-1436, 1962.

FAUL, Henry

1-63. Report on the operation of Barnaby, Summer, 1948: U. S. Geol. Survey open-file report, 32 p., 1963. (Report prepared for U. S. Atomic Energy Commission.)

2-63. (and STERN, T. W., and THOMAS, H. H., and ELMORE, P. L.) Ages of intrusion and metamorphism in the northern Appalachians: Am. Jour. Sci., v. 261, no. 1, p. 1-19, 1963.

FAUST, George Tobias

1-63. Phase transition in synthetic and natural leucite: Schweizer Mineralog. u. Petrog. Mitt. (Zürich, Switzerland), Band 43, Heft 1, p. 165-195, 1963.

FEININGER, T. Gustaf

1-62. Surficial geology of the Hope Valley quadrangle, Rhode Island: U. S. Geol. Survey Geol. Quad. Map GQ-166, 1962.

FELTIS, Richard D.
1-63. Semiannual report of water levels in selected wells in Utah, April 1963: U. S. Geol. Survey open-file report, 5 p., 1963. (Prepared in coop. with Utah State Engineer.)

FELTZ, Herman R.
1-62. (and WARK, J. W.) Solute degradation in the Potomac River basin: Art. 177 in U. S. Geol. Survey Prof. Paper 450-D, p. D186-D187, 1962.

FERGUSON, George Ernest
1-62. The relationship of the natural water systems of Green Swamp to water management in that area: Soil and Crop Sci. Soc. Florida Proc. 1961, v. 21, p. 293-299, 1962.
1-63. Advances in automatic sampling: Am. Water Works Assoc. Jour., v. 55, no. 3, p. 405-406, 1963.

FERRIANS, Oscar John, Jr.
1-63. Till-like glaciolacustrine deposits in the Copper River Basin, Alaska [abs.]: Geol. Soc. America Spec. Paper 73, p. 151, 1963.

FETH, John Henry
1-62. Calculating relative mobility of elements during weathering, using modal analyses of rocks--Sierra Nevada examples [abs.]: Am. Geophys. Union Trans., v. 43, no. 4, p. 447, 1962; correction, v. 44, no. 1, p. 206, 1963.
2-62. (and HEM, John David) Springs along the Mogollon Rim in Arizona, in New Mexico Geol. Soc., Mogollon Rim region, east-central Arizona, 13th Field Conf., Oct. 1962, Guidebook, p. 129-134, 1962.
1-63. Tertiary lake deposits in western conterminous United States: Science, v., 139, no. 3550, p. 107-110, 1963.
2-63. (and POLZER, W. L., and ROBERSON, C. E.) Sources of mineral constituents in ground water in the Sierra Nevada [abs.]: Geol. Soc. America Spec. Paper 73, p. 152, 1963; Ground Water, Jour. Natl. Water Well Assoc., v. 1, no. 2, p. 40, 1963.
3-63. (and HEM, J. D.) Reconnaissance of headwater springs in the Gila River drainage basin, Arizona: U. S. Geol. Survey Water-Supply Paper 1619-H, p. H1-H54, 1963.
4-63. Empirical studies of water from "monolithologic" terranes: U. S. Geol. Survey open-file report, 39 p., 1963.

FEULNER, Alvin J.
1-63. Water-supply potential in the Ohlson Mountain area, Kenai Peninsula, Alaska: U. S. Geol. Survey open-file report, 16 p., 1963.

FIERING, Myron B.
1-63. Use of correlation to improve estimates of the mean and variance: U.S. Geol. Survey Prof. Paper 434-C, p. C1-C9, 1963.

FINNELL, Tommy Lee
1-62. Recurrent movement on the Canyon Creek fault, Navajo County, Arizona: Art. 143 in U. S. Geol. Survey Prof. Paper 450-D, p. D80-D81, 1962.
1-63. (and FRANKS, P. C., and HUBBARD, H. A.) Geology, ore deposits, and exploratory drilling in the Deer Flat area, White Canyon district, San Juan County, Utah: U. S. Geol. Survey Bull. 1132, 114 p., 1963.

FISCHER, Richard Philip
1-61. Geochemistry and geology, Chap. 3 in Busch, P. M., Vanadium--A materials survey: U. S. Bur. Mines Inf. Circ. 8060, p., 26-32, 1961.
2-61. Resources, Chap. 4 in Busch, P. M., Vanadium--A materials survey: U. S. Bur. Mines Inf. Circ. 8060, p. 33-41, 1961.

FISCHER, William August
1-62. Reflection of soil-covered structure on infrared photography [abs.], in Symposium on detection of underground objects, materials and properties, Mar. 19-20, 1962, Proc.: Fort Belvoir, Virginia, U. S. Army Engineer Research and Devel. Labs., Corps of Engineers, p. 249, 1962.
2-62. (and SOUSA, T. M.) Preliminary experiments in photometric analysis of geologic units on the Moon, in Astrogeologic studies--Semiannual progress report, Feb. 26, 1961 to Aug. 24, 1961: U. S., Geol. Survey open-file report, p. 125-130, 1962.

FISHER, Frances Gilbert
1-62. (and MEYROWITZ, Robert) Brockite, a new calcium thorium phosphate from the Wet Mountains, Colorado: Am. Mineralogist, v. 47, nos. 11-12, p. 1346-1355, 1962.

FISHMAN, Marvin J.
1-63. (and SKOUGSTAD, M. W.) Indirect spectrophotometric determination of traces of bromide in water: Anal. Chemistry, v. 35, no. 2, p. 146-149, 1963.

FLAMMER, Gordon Hans
1-62. Ultrasonic measurement of suspended sediment: U. S. Geol. Survey Bull. 1141-A, p. A1-A48, 1962.

FLEISCHER, Michael
1-62. Fluoride content of ground water in the conterminous United States (maximum reported value for each county): U. S. Geol. Survey Misc. Geol. Inv. Map I-387, 1962.
2-62. (and ROBINSON, W. O.) Some problems of the geochemistry of fluorine [abs.]: Royal Soc. Canada Minutes Proc., 3d ser., v. 56, p. 29, 1962.
1-63. (and FAUST, G. T.) Studies on manganese oxide minerals--[Pt.] 7, Lithiophorite: Schweizer. Mineralog. u. Petrog. Mitt. (Zürich, Switzerland), Band 43, Heft 1, p. 197-216, 1963.

FLETCHER, Mary Henry
1-63. Study of multicomponent mixtures in solution with a vertical-axis transmission-type filter-fluorometer: Anal. Chemistry, v. 35, no. 3, p. 278-288, 1963.
2-63. A vertical-axis transmission-type filter-fluorometer for solutions: Anal. Chemistry, v. 35, no. 3, p. 288-292, 1963.

FORD, Arthur Barnes
1-62. (and AARON, J. M.) Bedrock geology of the Thiel Mountains, Antarctica: Science, v. 137, no. 3532, p. 751-752, 1962.

FORD, Arthur Barnes--Continued
2-62. The unknown mountains of Antarctica: Summit, v. 8, no. 12, p. 2-7, 1962.
1-63. (and HUBBARD, H. A., and STERN, T. W.) Lead-alpha ages of zircon in quartz monzonite porphyry, Thiel Mountains, Antarctica--A preliminary report: Art. 208 in U. S. Geol. Survey Prof. Paper 450-E, p. E105-E107, 1963.

FOSBERG, Francis Raymond
1-62. A brief survey of the cays of Arrecife Alacran, a Mexican atoll: Atoll Research Bull. 93, 30 p., 1962.
2-62. Miscellaneous notes on Hawaiian plants--[No.] 3: Bernice P. Bishop Mus. Occasional Papers, v., 23, no. 2, p. 29-44, 1962.
3-62. (and SACHET, M.-H.) Vascular plants recorded from Jaluit Atoll: Atoll Research Bull. 92, 39 p., 1962.

FOSTER, Helen Laura
1-61. Summary of the stratigraphy of the southern Ryukyu-retto: Pacific Sci. Cong., 9th, Bangkok, Thailand, 1957, Proc., v. 12, Geology and Geophysics, p. 341-344, 1961 [1962].
1-62. Memorial to Arnold Caverly Mason (1906-1961): Geol. Soc. America Bull., v. 73, no., 8, p. P87-P90, 1962.

FOSTER, James B.
1-62. Well design as a factor contributing to loss of water from the Floridan aquifer, eastern Clay County, Florida: Florida Geol. Survey Inf. Circ. 35, 10 p., 1962. (Prepared by U. S. Geological Survey in coop. with Florida Geological Survey.)

FOSTER, Margaret Dorothy
1-63. Interpretation of the composition of vermiculites and hydrobiotites, in Swineford, Ada, ed., Clays and clay minerals, V. 10: Natl. Conf. Clays and Clay Minerals, 10th, Austin, Texas, Oct. 1961, Proc., p. 70-89, 1963. (Issued as Earth Science Ser. Mon. 12 of Pergamon Press by Macmillan Co., New York.)

FOSTER, Roy Woodrow
1-62. (and others) Road log from Gallup, New Mexico, to Globe, Arizona, in New Mexico Geol. Soc., Mogollon Rim region, east-central Arizona, 13th Field Conf., Oct. 1962, Guidebook, p. 10-25, 1962. (Others include J. P. Akers, P. W. Johnson, M. E. Cooley, T. L. Finnell, E. J. McKay, and A. F. Shride.)

FOURNIER, Robert Orville
1-62. (and ROWE, J. J.) The solubility of cristobalite along the three-phase curve, gas plus liquid plus cristobalite: Am. Mineralogist, v. 47, nos. 7-8, p. 897-902, 1962.

FOXWORTHY, Bruce LaVerne
1-63. (and WASHBURN, R. L.) Ground water in the Pullman area, Whitman County, Washington: U. S. Geol. Survey Water-Supply Paper 1655, 71 p., 1963.

FRANK, Florian J.
1-63. (and OLMSTED, F. H.) Progress report on subsurface geologic investigation in the Yuma area [Arizona]: U. S. Geol. Survey open-file report, 7 p., 1963.

FREDERICK, Bernard James
1-62. (and RECK, C. W., and CARTER, R. W.) Use of a radioisotope to measure water discharge: Art. 176 in U. S. Geol. Survey Prof. Paper 450-D, p. D185-D186, 1962.

FRIEDMAN, Irving
1-62. (and MACHTA, Lester, and SOLLER, Ralph) Water-vapor exchange between a water droplet and its environment: Jour. Geophys. Research, v. 67, no. 7, p. 2761-2766, 1962; abs., Jour. Geophys. Research, v. 67, no. 9, p. 3559, 1962.
2-62. (and SMITH, R. L., and LEVIN, Betsy) Water and deuterium in phenocrysts in glassy silicic volcanic rocks [abs.]: Jour. Geophys. Research, v. 67, no. 9, p. 3559, 1962.
1-63. (and HALL, W. E.) Fractionation of $O^{18}/O^{16}$ between coexisting calcite and dolomite: Jour. Geology, v. 71, no. 2, p. 238-243, 1963.

FRISCHKNECHT, Frank Conrad
1-63. (and PETRAFESO, F. A., and others) Aeromagnetic map of the Canyon del Muerto quadrangle, Apache County, Arizona: U. S. Geol. Survey Geophys. Inv. Map GP-406, 1963.
2-63. (and PETRAFESO, F. A., and others) Aeromagnetic map of the Nazlini quadrangle, Apache County, Arizona: U. S. Geol. Survey Geophys. Inv. Map GP-407, 1963.
3-63. (and PETRAFESO, F. A., and others) Aeromagnetic map of part of the Toh-Atin Mesa quadrangle, Apache County, Arizona: U. S. Geol. Survey Geophys. Inv. Map GP-403, 1963.
4-63. (and PETRAFESO, F. A., and others) Aeromagnetic map of part of the Los Gigantes Buttes quadrangle, Apache County, Arizona: U. S. Geol. Survey Geophys. Inv. Map GP-404, 1963.
5-63. (and PETRAFESO, F. A., and others) Aeromagnetic map of the Yellowstone Canyon quadrangle, Apache County, Arizona: U. S. Geol. Survey Geophys. Inv. Map GP-405, 1963.

FRITTS, Crawford Ellsworth
1-62. Age and sequence of metasedimentary and metavolcanic formations northwest of New Haven, Connecticut: Art. 128 in U. S. Geol. Survey Prof. Paper 450-D, p. D32-D36, 1962.
2-62. The barite mines of Cheshire: Cheshire, Connecticut, Cheshire Hist. Soc., 36 p., 1962.
1-63. Late Newark fault versus pre-Newark peneplain in Connecticut: Am. Jour. Sci., v. 261, no. 3, p. 268-281, 1963.
2-63. Bedrock geology of the Mount Carmel and Southington quadrangles, Connecticut [abs.]: Dissert. Abs., v. 23, no. 10, p. 3863, 1963.

FURNESS, Lawton Williams
1-62. Kansas streamflow characteristics--Pt. 4, Storage requirements to sustain gross reservoir outflow: Kansas Water Resources Board Tech. Rept., 4, 177 p., 1962. (Prepared by the U. S. Geological Survey in coop. with Kansas Water Resources Board.)

GAIR, Jacob Eugene
1-62. Geology and ore deposits of the Nova Lima and Rio Acima quadrangles, Minas Gerais, Brazil: U. S. Geol. Survey Prof. Paper 341-A, p. A1-A67, 1962.
1-63. (and THADEN, R. E., and JONES, B. F.) Geologic maps of the Marquette and Sands quadrangles, Michigan: U. S. Geol. Survey open-file report, 2 maps with explanation and cross sections, 1963.

GALLAGHER, David
1-62. (and KLEPPER, M. R., and OVERSTREET, W. C., and SAMPLE, R. D., and CHEONG, C. H.) Mineral resources of Korea: U. S. Geol. Survey open-file report, 2239 p., 1962.
1-63. (and KLEPPER, M. R., and OVERSTREET, W. C., and SAMPLE, R. D.) Mineral resources of Korea: U. S. Operations Mission Korea, Industry and Mining Div., Mining Br., [894 p.] in 10 pts. (paged separately) incl. 2 pts. on Index-Introduction-Geology-Bibliography and Bibliographical Index and 8 pts. (6 v.) on specific commodities, 1963. (Prepared by U. S. Geological Survey in coop. with Geological Survey, Republic of Korea.)

GALLI OLIVIER, Carlos
1-62. (and DINGMAN, R. J.) Cuadrangulos Pica, Alca, Matilla y Chacarilla, con un estudio sobre los recursos de agua subterránea, Provincia de Tarapacá: Chile Inst. Inv. Geol. Carta Geol. Chile, v. 3, nos. 2-5, 125 p., 1962. (Prepared in cooperation with U. S. Agency for International Development and U. S. Geological Survey.)

GARD, Leonard Meade, Jr.
1-62. Natural state stress fields: U. S. Atomic Energy Comm. Rept. PNE-130F, p. 80-84, 1962. (Report prepared for U. S. Atomic Energy Commission by U. S. Geological Survey for Project Gnome.)
2-62. (and COOPER, J. B.) Geology: U. S. Atomic Energy Comm. Rept. PNE-130F, p. 11-47, 1962. (Report prepared for U. S. Atomic Energy Commission by U. S. Geological Survey for Project Gnome.)
3-62. (and MOURANT, W. A.) Detailed description of rocks in Gnome shaft: U. S. Atomic Energy Comm. Rept. PNE-130F, p. 160-187, 1962. (Report prepared for U. S. Atomic Energy Commission by U. S. Geological Survey for Project Gnome.)
1-63. Nuclear explosions--Some geologic effects of the Gnome shot: Science, v. 139, no. 3558, p. 911-914, 1963.
2-63. (and EMERICK, W. L.) Geologic effects of the Project Gnome nuclear detonation on the Salado Formation near Carlsbad, New Mexico [abs.]: Geol. Soc. America Spec. Paper 73, p. 158, 1963.

GARRETT, Arthur Angus
1-62. Artificial recharge of basalt aquifers, Walla Walla, Washington: Art. 107 in U. S. Geol. Survey Prof. Paper 450-C, p. C116-C117, 1962.

GARZA, Sergio
1-62. (and WESSELMAN, J. B.) Geology and ground-water resources of Winkler County, Texas: U. S. Geol. Survey Water-Supply Paper 1582, 162 p., 1962 [1963].
1-63. Chemical analyses of water from observation wells in the Edwards and associated limestones, San Antonio area, Texas: U. S. Geol. Survey open-file report, 56 p., 1963.
2-63. Zone of transition between water of good quality and saline water in the Edwards Limestone in the Balcones fault zone, Texas [abs.]: Geol. Soc. America Spec. Paper 73, p. 158, 1963; Ground Water, Jour. Natl. Water Well Assoc., v. 1, no. 2, p. 39, 1963.

GATES, George Oscar
1-62. Exploration and development of oil and gas resources of Alaska, in Econ. Comm. Asia and Far East (ECAFE), Sub.-Comm. on Mineral Resources Devel., 2d Symposium on the Development of the Petroleum Resources of Asia and the Far East--U. S. Contr.: Washington, D. C., U. S. Dept. of the Interior, p. 102-107, 1962.
1-63. (and GRYC, George) Structure and tectonic history of Alaska, in Backbone of the Americas: Am. Assoc. Petroleum Geologists Mem. 2, p. 264-277, 1963.

GATES, Joseph Spencer
1-62. Geohydrologic evidence of a buried fault in the Erda area, Tooele Valley, Utah: Art. 142 in U. S. Geol. Survey Prof. Paper 450-D, p. D78-D80, 1962.

GAULT, Donald E.
1-62. (and SHOEMAKER, E. M., and MOORE, H. J., 2d) The flux and distribution of fragments ejected from the lunar surface by meteoroid impact [abs.]: Am. Geophys. Union Trans., v. 43, no. 4, p. 465, 1962.
1-63. (and SHOEMAKER, E. M., and MOORE, H. J., 2d) Spray ejected from the lunar surface by meteoroid impact, in Astrogeologic studies--Annual progress report, Aug. 25, 1961 to Aug. 24, 1962, Pt. D, Studies for space flight program: U. S. Geol. Survey open-file report, p. 6-53, 1963.

GEORGE, John R.
1-63. Sedimentation in the Stony Brook basin, New Jersey, 1956-59: U. S. Geol. Survey open-file report, 67 p., 1963.

GEORGE, William Owsley
1-62. (and WOOD, L. A., and REEVES, R. D.) Hydrogeology of the Edwards and associated limestones, Field excursion no. 11, November 10-11, 1962, in Geol. Soc. America, Geology of the Gulf Coast and central Texas and guidebook of excursions: Houston, Texas, Houston Geol. Soc., p. 354-384, 1962.

GESSEL, Clyde D.
1-62. (and RUTLEDGE, D. H.) Large-scale mapping of Lake Powell: Am. Soc. Civil Engineers Proc., v. 88, Jour. Surveying and Mapping Div., no. SU 1, p. 17-27, 1962.

GEYNE, Arturo R.
1-63. (and FRIES, Carl, Jr., and SEGERSTROM, Kenneth, and BLACK, R. F., and WILSON, I. F.) Geología y yacimientos minerales del distrito de Pachuca-Real del Monte, Estado de Hidalgo, México: México Consejo Recursos Nat. no Renovables Pub. 5E, 220 p., 1963.

GILBERT, Clarence R.
1-63. (and COMMONS, G. G., and KOBERG, G. E., and KENNON, F. W.) Hydrologic studies of small watersheds, Honey Creek basin, Collin and Grayson Counties, Texas, 1953-59: U. S. Geol. Survey open-file report, 102 p., 1963.
2-63. (and MYERS, B. N., and LEGGAT, E. R., and WELBORN, C. T.) Hydrologic studies of small watersheds, Elm Fork Trinity River basin, Montague and Cooke Counties, Texas, 1956-60: U. S. Geol. Survey open-file report, 77 p., 1963.

GILDERSLEEVE, Benjamin
1-62. Geology of the Polkville quadrangle, Kentucky: U. S. Geol. Survey [Geol., Quad. Map] GQ-194, 1962. (Prepared in coop. with Kentucky Geological Survey.)
1-63. Geology of the Bristow quadrangle, Kentucky: U. S. Geol. Survey Geol. Quad. Map GQ-216, 1963.

GILL, Harold Edward
1-62. Ground-water resources of Cape May County, N. J.--Salt-water invasion of principal aquifers: New Jersey Dept. Conserv. and Econ. Devel., Div. Water Policy and Supply, Spec. Rept. 18, 171 p., 1962. (Prepared by U. S. Geological Survey in coop. with the State of New Jersey.)

GILLULY, James
1-62. The place of geology in American life: South Dakota State Geol. Survey Educ. Ser., book 1, 17 p., 1962.
1-63. Memorial to Parker Davies Trask (1899-1961): Geol. Soc. America Bull., v. 74, no. 1, p. P13-P19, 1963.
2-63. Volcanism, tectonism, and plutonism in the western United States [abs.]: Am. Geophys. Union Trans., v. 44, no. 1, p. 114, 1963.

GIROUX, Paul R.
1-62. Summary of ground-water conditions in Michigan, 1961: Michigan Geol. Survey Div. Water Supply Rept. 6, 98 p., 1962. (Prepared in coop. with U. S. Geological Survey.)

GIUSTI, Ennio Vincent
1-62. A relation between floods and drought flows in the Piedmont province in Virginia: Art. 112 in U. S. Geol. Survey Prof. Paper 450-C, p. C128-C129, 1962.
2-62. An investigation of Piedmont streams in terms of their geomorphology and runoff characteristics [abs.]: Masters Abs., v. 1, no. 2, p. 16, 1962.
1-63. (and SCHNEIDER, W. J.) Comparison of drainage on topographic maps of the Piedmont province: Art. 212 in U. S. Geol. Survey Prof. Paper 450-E, p. E118-E120, 1963.

GOLDICH, Samuel Stephen
1-62. (and HEDGE, C. E.) Dating of the Precambrian of the Minnesota River valley, Minnesota [abs.]: Jour. Geophys. Research, v. 67, no. 9, p. 3561-3562, 1962.
1-63. (and INGAMELLS, C. O.) Comparative determinations of potassium and rubidium [abs.]: Am. Geophys. Union Trans., v. 44, no. 1, p. 109, 1963.

GOLDSMITH, Richard
1-62. Surficial geology of the New London quadrangle, Connecticut-New York: U. S. Geol., Survey [Geol. Quad. Map] GQ-176, 1962.
2-62. Surficial geology of the Montville quadrangle, Connecticut: U. S. Geol. Survey Geol. Quad. Map GQ-148, 1962.

GOODE, Harry Donald
1-62. Cooperative investigations of ground water in the Sevier River basin: Pacific Southwest Inter-Agency Comm., 61-3 Mtg., Richfield, Utah, Sept. 1961, Minutes, 5 p., paged separately, 1962.

GORDON, Ellis Davis
1-63. Cooperative ground-water investigations in Wyoming: Wyoming State Engineer, 36th Bienn. Rept. 1961-62, p. 105-115, [1963].

GOTT, Garland Bayard
1-63. (and SCHNABEL, R. W.) Geology of the Edgemont NE quadrangle, Fall River and Custer Counties, South Dakota: U. S. Geol. Survey Bull. 1063-E, p. 127-190, 1963.

GOTTFRIED, David
1-63. (and MOORE, Roosevelt, and CAMPBELL, E. Y.) Thorium and uranium in some volcanic rocks from the circum-Pacific province: Art. 202 in U. S. Geol. Survey Prof. Paper 450-E, p. E85-E89, 1963.

GOTTSCHALL, Irwin
1-62. A bibliography of maps of Civil War battlefield areas: U. S. Geol. Survey Circ. 462, 33 p., 1962.

GOUDARZI, Gus Hossein
1-62. A geologic report on the iron deposit of the Shatti Valley area of the Fezzan Province, Libya: U. S. Geol. Survey open-file report, 77 p., 1962.
2-62. Idri salt deposits, Fezzan Province, Libya: U. S. Geol. Survey open-file report, 36 p., 1962.
3-62. Pisida salt deposit, Libya: U. S. Geol. Survey open-file report, 27 p., 1962.
4-62. Report on Marada, Pisida, Idri and Tauorga salt deposits in Libya: U. S. Geol. Survey open-file report, 36 p., 1962.

GRANGER, Harry Clifford
1-62. Clays in the Morrison Formation and their spatial relation to the uranium deposits at Ambrosia Lake, New Mexico: Art. 124 in U. S. Geol. Survey Prof. Paper 450-D, p. D15-D20, 1962.
2-62. (and RAUP, R. B., Jr.) Reconnaissance study of uranium deposits in Arizona: U.. S. Geol. Survey Bull. 1147-A, p. A1-A54, 1962.
1-63. Mineralogy of uranium deposits in the southern San Juan Basin mineral belt: New Mexico Bur. Mines and Mineral Resources Mem. 15, p. 21-37, 1963.

GRANT, Richard Evans
1-63. Unusual attachment of a Permian linoproductid brachiopod: Jour. Paleontology, v. 37, no. 1, p. 134-140, 1963.

GRANTZ, Arthur
1-62. (and WHITE, D. E., and WHITEHEAD, H. C., and TAGG, A. R.) Saline springs, Copper River, Lowland, Alaska: Am. Assoc. Petroleum Geologists Bull., v. 46, no. 11, p. 1990-2002, 1962.
2-62. (and ZIETZ, Isidore) Regional aeromagnetic surveys for petroleum in Alaska, in Econ. Comm. Asia and Far East (ECAFE), Sub.-Comm. on Mineral Resources Devel., 2d Symposium on the Development of the Petroleum Resources of Asia and the Far East--U. S. Contr.: Washington, D. C., U. S. Dept. of the Interior, p. 108-117, 1962.
1-63. (and ZIETZ, Isidore, and ANDREASEN, G. E.) An aeromagnetic reconnaissance of the Cook Inlet area, Alaska: U. S. Geol. Survey Prof. Paper 316-G, p. 117-134, 1963.

GREEN, Jack Harlan
1-62. Compaction of the aquifer system and land subsidence in the Santa Clara Valley, California: Art. 172 in U. S. Geol. Survey Prof. Paper 450-D, p.nD175-D178, 1962.
2-62. The effect of artesian-pressure decline on confined aquifer systems in areas of land subsidence [abs.]: Jour. Geophys. Research, v. 67, no. 9, p. 3532, 1962.
1-63. The effect of artesian-pressure decline on confined aquifer systems and its relation to land subsidence: U. S. Geol. Survey open-file report, 25 p., 1963.

GREENMAN, David Wolcott
1-63. Hydrology and scientific reclamation in the Punjab, West Pakistan, in U. S. Dept. State, Natural resources--Energy, water and river basin development: United Nations Conf. Application Sci. and Technology Benefit Less Developed Areas, Geneva, 1963, U. S. Papers, v. 1, p. 332-342, 1963.

GREVE, Gordon Madsen
1-63. (and CLEMENT, W. G.) Principal facts for gravity stations in the San Francisco Bay area, California: U. S. Geol. Survey open-file report, 26 p., 1963.

GRIFFITTS, Wallace Rush
1-62. (and LARRABEE, D. M., and NORTON, J. J.) Beryllium in the United States, exclusive of Alaska and Hawaii: U.nS. Geol. Survey Mineral Inv. Resource Map MR-35, 1962.
2-62. (and YATES, R. G., and OVERSTREET, W. C.) Preliminary geologic map of the southwest quarter of the Shelby quadrangle, Cleveland and Rutherford Counties, North Carolina: U. S. Geol. Survey Mineral Inv. Field Studies Map MF-252, 1962.

GRIMALDI, Frank Saverio
1-61. (and BREGER, I. A.) Niobium content of soils from West Africa: Geochim. et Cosmochim. Acta, v. 25, no. 1, p. 71-80, 1961.

GRISCOM, Andrew
1-63. Tectonic significance of the Bouguer gravity field of the Appalachian system [abs.]: Geol. Soc. America Spec. Paper 73, p. 163-164, 1963.

GROSSMAN, Irving Gross
1-62. Stratigraphy and hydrology of the Juana Díaz Formation in the Yauco area, Puerto Rico: Art. 137 in U. S. Geol. Survey Prof. Paper 450-D, p. D62-D63, 1962.

GUALTIERI, James Louis
1-62. Exploration of the Jefren gypsum-anhydrite deposit, Tripolitania, Libya: U. S. Geol. Survey open-file report, 65 p., 1962.

GULBRANDSEN, Robert Allen
1-63. (and GOLDICH, S. S., and Thomas, H.,H.) Glauconite from the Precambrian Belt Series, Montana: Science, v. 140, no. 3565, p. 390-391, 1963..

GUTENTAG, Edwin D.
1-63. (and FADER, S. W.) Pleistocene and Pliocene stratigraphy in Grant and Stanton Counties, Kansas: Geol. Soc. America Spec. Paper 73, p. 164, 1963.

HACKMAN, Robert Joseph
1-62. Geologic map and sections of the Kepler region of the Moon: U. S. Geol. Survey [Misc. Geol. Inv.] Map I-355(LAC-57), 1962.
1-63. A lunar isotonal map [abs.]: Am. Soc. Photogrammetry, 29th Ann. Mtg., Washington, D. C., Mar. 1963, Abs. Paper, p. 10-11, 1963.
2-63. Photointerpretation of the lunar surface [abs.]: Am. Soc. Photogrammetry, 29th Ann. Mtg., Washington, D. C., Mar. 1963, Abs. Papers, p. 46, 1963.
3-63. Isotonal map, in Astrogeologic studies--Annual progress report, Aug. 25, 1961 to Aug. 24, 1962, Pt. A, Lunar and planetary investigations: U. S. Geol. Survey open-file report, p. 58-59 and sheet in pocket, 1963.
4-63. Stratigraphy and structure of the Apennine region of the Moon, in Astrogeologic studies--Annual progress report, Aug. 25, 1961 to Aug. 24, 1962, Pt. A, Lunar and planetary investigations: U. S. Geol. Survey open-file report, p. 2-10, 1963.

HADLEY, Jarvis Bardwell
1-63. Correlation between isotopic ages, crustal heating, and sedimentation in the Appalachian region [abs.]: Geol. Soc. America, Southeastern Sec., Ann. Mtg., Roanoke, Virginia, Apr. 1963, Program, p. 14, 1963.

HAIGLER, Leonard Boyd
1-62. Geologic notes on the Delaware basin: New Mexico Bur. Mines and Mineral Resources Circ. 63, 14 p., 1962. (Published in coop. with U. S. Geological Survey.)

HALBERG, Henry Nicholas
1-62. (and HUNT, O. P., and PAUSZEK, F. H.) Water resources of the Utica-Rome area, New York: U. S. Geol. Survey Water-Supply Paper 1499-C, p. C1-C46, 1962 [1963].

HALL, Wayne Everett
1-62. (and MacKEVETT, E. M., Jr.) Geology and ore deposits of the Darwin quadrangle, Inyo County, California: U. S. Geol. Survey Prof. Paper 368, 87 p., 1962 [1963].

HALL, Wayne Everett--Continued
2-62. (and STEPHENS, H. G.) Preliminary geologic map of the Panamint Butte quadrangle, Inyo County, California: U. S. Geol. Survey Mineral Inv. Field Studies Map MF-251, 1962. (Prepared in coop. with California Div. Mines and Geology.)

HALLGARTH, Walter Ervin
1-62. Upper Paleozoic rocks exposed in Straight Wash Canyon, San Rafael Swell, Utah: Am. Assoc. Petroleum Geologists Bull., v. 46, no. 8, p. 1494-1501, 1962.
2-62. (and SKIPP, B. A. L.) Age of the Leadville Limestone in the Glenwood Canyon, western Colorado: Art. 129 in U. S. Geol. Survey Prof. Paper 450-D, p. D37-D38, 1962.

HALLIDAY, James
1-63. The vital communications link--Photoidentification of horizontal control [abs.]: Am. Soc. Photogrammetry, 29th Ann. Mtg., Washington, D. C., Mar. 1963, Abs. Papers, p. 60, 1963.

HAMILTON, Warren Bell
1-63. Tectonics of Antarctica, in Backbone of the Americas: Am. Assoc. Petroleum Geologists Mem. 2, p. 4-15, 1963..
2-63. Island Park caldera, eastern Idaho [abs.]: Geol. Soc. America Spec. Paper 73, p. 40-41, 1963.
3-63. Columbia River basalt in the Riggins quadrangle, western Idaho: U. S. Geol. Survey Bull. 1141-L, p. L1-L37, 1963.
4-63. Trondhjemite in the Riggins quadrangle, western Idaho: Art. 205 in U. S. Geol. Survey Prof. Paper 450-E, p. E98-E101, 1963.
5-63. (and MYERS, W. B.) Menan Buttes, cones of glassy basalt tuff in the Snake River Plain, Idaho: Art. 211 in U. S. Geol. Survey Prof. Paper 450-E, p. E114-E118, 1963.
6-63. Overlapping of late Mesozoic orogens in western Idaho: Geol. Soc. America Bull., v. 74, no. 6, p. 779-787, 1963.

HAMPTON, Eugene R.
1-63. Ground water in the coastal dune area near Florence, Oregon: U. S. Geol. Survey Water-Supply Paper 1539-K, p. K1-K36, 1963.

HANNUM, Curtis H.
1-63. Floods of July 29 and 30, 1961, in eastern Kentucky: U. S. Geol. Survey open-file report, 41 p., 1963.

HANSEN, Arnold J., Jr.
1-62. Ground-water map of the Clayville quadrangle, Rhode Island, showing water-bearing formations and related ground-water data: Rhode Island and Providence Plantations Water Resources Coordinating Board Ground-Water Map GWM 17, 1962. (Prepared in coop. with U. S. Geological Survey.)
2-62. Ground-water map of the Rhode Island parts of the Thompson and East Killingly quadrangles, showing water-bearing formations and related ground-water data: Rhode Island and Providence Plantations Water Resources Coordinating Board Ground-Water Map GWM 18, 1962. (Prepared in coop. with U. S. Geological Survey.)
1-63. (and SCHINER, G. R.) Ground-water levels in Rhode Island, 1960-1962: U. S. Geol. Survey open-file report, 75 p., 1963.

HANSEN, Wallace Ray
1-62. (and POST, E. V., and PRICHARD, G. E.) The Frozen Sandstone, a new member of the Breathitt Formation of eastern Kentucky: Art. 75 in U. S. Geol. Survey Prof. Paper 450-C, p. C46-C49, 1962.
1-63. (and JOHNSTON, J. E.) Geology of the Landsaw quadrangle, Kentucky: U. S. Geol. Survey Geol. Quad. Map GQ-201, 1963. (Prepared in coop. with Kentucky Geological Survey.)

HANSHAW, Bruce B.
1-63. Electrochemical determination of cation-exchange constants for compacted clays [abs.]: Geol.,Soc. America Spec. Paper 73, p. 166, 1963.

HARRIS, Leonard Dorreen
1-62. (and STEPHENS, J. G., and MILLER, R. L.) Geology of the Coleman Gap quadrangle, Tennessee-Virginia: U. S. Geol. Survey [Geol. Quad. Map] GQ-188, 1962 [1963].
2-62. (and ZIETZ, Isidore) Development of Cumberland overthrust block in vicinity of Chestnut Ridge fenster in southwest Virginia: Am. Assoc. Petroleum Geologists Bull., v. 46, no. 12, p. 2148-2160, 1962.
1-63. Thrusting developed after folding in the Valley and Ridge province, southwest Virginia: Art. 185 in U. S. Geol. Survey Prof. Paper 450-E, p. E22-E25, 1963.

HARRIS, William H.
1-63. (and WILDER, H. B.) Stratification of fresh and salt water on barrier islands as a result of changes in sediment permeability [abs.]: Geol. Soc. America Spec. Paper 73, p. 167, 1963; Ground Water, Jour. Natl. Water Well Assoc., v. 1, no. 2, p.,39, 1963.

HARSHBARGER, John William
1-63. (and FERRIS, J. G.) Interdisciplinary training program in scientific hydrology: Ground Water, Jour. Natl. Water Well Assoc., v. 1, no. 2, p. 11-14, 1963.

HARSHMAN, Elbert Nelson
1-62. Alteration as a guide to uranium ore, Shirley Basin, Wyoming: Art. 122, in U. S. Geol. Survey Prof. Paper 450-D, p. D8-D10, 1962.

HART, Donald L., Jr.
1-63. Ground-water levels in observation wells in Oklahoma, 1956-60: U. S. Geol. Survey open-file report, 188 p., 1963.
2-63. Ground-water levels in observation wells in Oklahoma, 1956-60: Oklahoma Water Resources Board, 196 p., 1963. (Prepared by U. S. Geological Survey in coop. with Oklahoma Water Resources Board.)

HARVEY, Edward Joseph
1-63. (and SHOWS, T. N.) Well records, logs, and water analyses, George and Jackson Counties, Mississippi: Mississippi Board Water Comm. Bull. 63-1, 43 p., 1963. (Prepared by U. S.,Geological Survey in coop. with Jackson County Port Authority and Board of Supervisors.)

HARVEY, Edward Joseph--Continued
2-63. Compilation of aquifer test data for Mississippi: Mississippi Board Water Comm. Bull. 63-4, 10 p., 1963. (Prepared by U. S. Geological Survey in coop. with Mississippi Board of Water Commissioners.)
HASLER, J. William
1-63. Interim geological investigations in the U12e.07 tunnel, Nevada Test Site, Nye County, Nevada: U. S. Geol. Survey Rept. TEI-334, open-file report, 22 p., 1963. (Report prepared for U. S. Atomic Energy Commission.)
HASTINGS, Warren William
1-62. New advances in water-resources research: U. S. Geol. Survey open-file report, 21 p., 1962.
HATCH, Norman Lowrie, Jr.
1-63. Geology of the Bernstadt quadrangle, Kentucky: U. S. Geol. Survey Geol. Quad. Map GQ-202, 1963. (Prepared in coop. with Kentucky Geological Survey.)
2-63. Geology of the Billows quadrangle, Kentucky: U. S. Geol. Survey Geol. Quad. Map GQ-228, 1963. (Prepared in coop. with Kentucky Geological Survey.)
HATHAWAY, John Cummins
1-62. (and SCHLANGER, S. O.) Nordstrandite from Guam: Nature (London), v. 196, no. 4851, p. 265-266, 1962.
HAUSHILD, William L.
1-63. (and KRUSE, Gordon) Unsteady flow of ground water into a surface reservoir: Am. Soc. Civil Engineers Trans. 1962, v. 127, pt. 1, p. 408-415; reply to discussion, p. 422-424, 1963.
HAWLEY, Charles Caldwell
1-60. (and SHARP, W. N.) Beryl, in Del Rio, S. M., compiler, Mineral resources of Colorado, first sequel: Denver, Colorado Mineral Resources Board, p. 240-241, 1960.
HAYNES, Donald D.
1-62. Geology of the Park City quadrangle, Kentucky: U. S. Geol. Survey Geol. Quad. Map GQ-183, 1962. (Prepared in coop. with Kentucky Geological Survey.)
HEALEY, Don L.
1-62. (and MILLER, C. H.) Gravity survey of the Nevada Test Site and vicinity, Nye, Lincoln, and Clark Counties, Nevada--Interim report: U. S. Geol. Survey Rept. TEI-827 (open-file report), 36 p., 1962. (Report prepared for U. S. Atomic Energy Commission.)
HEALY, Henry G.
1-62. Piezometric surface and areas of artesian flow of the Floridan aquifer in Florida, July 6-17, 1961: Florida Geol. Survey Map Ser., no. 4, 1962. (Prepared by U. S. Geological Survey in coop. with Florida Geological Survey.)
HEALY, John H.
1-63. (and STEWART, S. W., and JACKSON, W. H.) Crustal studies in the western Cordillera [abs.]: Geol. Soc. America Spec. Paper 73, p. 42, 1963.
HEATH, Ralph Carr
1-63. Ground-water studies in Saratoga County, New York--Pt. 1, Summary of ground-water conditions in Saratoga County: New York Water Resources Comm. Bull. GW-49, p. 3-42, 1963.
2-63. (and TANNENBAUM, J. A.) Ground-water studies in Saratoga County, New York--Pt. 3, Ground-water resources of Saratoga National Historical Park and vicinity: New York Water Resources Comm. Bull. GW-49, p. 77-128, 1963.
HEDGE, Carl E.
1-61. Sodium-potassium ratios in muscovites as a geothermometer [abs.]: Arizona Geol. Soc. Digest, v. 4, p. 184, 1961.
1-63. (and WALTHALL, F. G.) Radiogenic strontium-87 as an index of geologic processes: Science, v. 140, no. 3572, p. 1214-1217, 1963; abs., Am. Geophys. Union Trans., v. 44, no. 1, p. 112, 1963.
HEINDL, Leopold Alexander
1-62. Ground-water shadows and buried topography, San Xavier Indian Reservation, Pima County, Arizona: Art. 109 in U. S. Geol. Survey Prof. Paper 450-C, p. C120-C122, 1962.
2-62. (and COSNER, O. J., and PAGE, H.,G., and ARMSTRONG, C. A., and KISTER, L. R., Jr.) Summary of occurrence of ground water on the Papago Indian Reservation, Arizona: U. S. Geol. Survey Hydrol. Inv. Atlas HA-55, 1962.
1-63. (and ARMSTRONG, C. A.) Geology and ground-water conditions in the Gila Bend Indian Reservation, Maricopa County, Arizona: U. S. Geol. Survey Water-Supply Paper 1647-A, p. A1-A47, 1963.
2-63. Cenozoic geology in the Mammoth area, Pinal County, Arizona: U. S. Geol. Survey Bull. 1141-E, p. E1-E41, 1963.
HELY, Allen Grant
1-63. Hydrologic regimen of the Salton Sea [California], with a section by Burdge Irelan: U. S. Geol. Survey open-file report, 18 p., 1963.
HEM, John David
1-61. Some aspects of chemical equilibrium in ground water, in U. S. Public Health Service, 1961 Symposium on Ground-Water Contamination: Robert A. Taft Sanitary Eng. Center Tech. Rept. W61-5, p. 20-26, 1961.
1-62. Chemical equilibriums affecting the behavior of manganese in natural water [abs.]: Jour. Geophys. Research, v. 67, no. 9, p. 3564, 1962.
2-62. Discussion of "Diatomite filtration for removal of iron and manganese," by G. J. Coogan (Am. Water Works Assoc. Jour., v. 54, no. 12, p. 1507-1517, 1962): Am. Water Works Assoc. Jour., v. 54, no. 12, p. 1517, 1962.
1-63. Manganese complexes with bicarbonate and sulfate in natural water: Jour. Chem. and Eng. Data, v. 8, no. 1, p. 99-101, 1963.
2-63. Chemical equilibria and rates of manganese oxidation: U. S. Geol. Survey Water-Supply Paper 1667-A, p. A1-A64, 1963.

HEMPHILL, William R.
1-63. (and KIDWAI, A. H.) The application of photogeology and photogrammetry to geological surveys of natural resources in Pakistan, in U. S. Dept. State, Natural resources--Minerals and mining, mapping and geodetic control: United Nations Conf. Application Sci. and Technology Benefit Less Developed Areas, Geneva, 1963, U. S. Papers, v. 2, p. 194-206, 1963.
HENBEST, Lloyd George
1-62. New members of the Bloyd Formation of Pennsylvanian age, Washington County, Arkansas: Art. 131 in U. S. Geol. Survey Prof. Paper 450-D, p. D42-D44, 1962.
2-62. Type sections for the Morrow Series of Pennsylvanian age, and adjacent beds, Washington County, Arkansas: Art. 130 in U.. S. Geol. Survey Prof. Paper 450-D, p. D38-D41, 1962.
HENDERSON, John Richard
1-62. (and CHANDLER, E. J., and others) Aeromagnetic map of the Ramsey quadrangle, Passaic and Bergen Counties, New Jersey, and Rockland County, New York: U.,S. Geol. Survey Geophys. Inv. Map GP-344, 1962.
2-62. (and SMITH, F. C., and others) Aeromagnetic map of parts of the Monroe and Maybrook quadrangles, Orange County, New York: U. S. Survey Geophys. Inv. Map GP-339, 1962.
3-62. (and VARGO, J. L., and others) Aeromagnetic map of part of the Dillingham quadrangle, Alaska: U. S. Geol. Survey Geophys. Inv. Map GP-352, 1962.
1-63. (and GILBERT, F. P., and others) Aeromagnetic map of the Chain Lakes quadrangle, Franklin and Somerset Counties, Maine: U. S. Geol. Survey Geophys. Inv. Map GP-330, 1963.
2-63. (and JOHNSON, R. W., Jr., and GILBERT, F. P.) Aeromagnetic map of the Wilmington, Delaware, area and adjacent parts of Pennsylvania and Maryland: U. S. Geol. Survey Geophys. Inv. Map GP-363, 1963.
3-63. (and WHITE, W. S., and ZIETZ, Isidore) Preliminary interpretation of an aeromagnetic survey in north-central Iowa: U. S. Geol. Survey open-file report, 27 p., 1963. (Prepared in coop. with Iowa Geological Survey.)
4-63. (and GILBERT, F. P., and others) Aeromagnetic map of the Kennebago Lake quadrangle, Franklin County, Maine: U. S.,Geol. Survey Geophys. Inv. Map GP-332, 1963.
5-63. (and SMITH, C. W., and others) Aeromagnetic map of the Moosehead Lake quadrangle and part of the First Roach Pond quadrangle, Piscataquis and Somerset Counties, Maine: U. S. Geol. Survey Geophys. Inv. Map GP-334, 1963.
6-63. (and WHITE, B. L., and others) Aeromagnetic map of Long Valley and northern Owens Valley, California: U. S. Geol. Survey Geophys. Inv. Map GP-329, 1963.
7-63. (and CHANDLER, E. J., and others) Aeromagnetic map of parts of the Paterson and Orange quadrangles, Essex, Passaic, and Bergen Counties, New Jersey: U. S. Geol. Survey Geophys. Inv. Map GP-345, 1963.
8-63. (and TYSON, N. S., and Paige, J. R.) Aeromagnetic map of the Wausau area, Wisconsin: U. S. Geol. Survey Geophys. Inv. Map GP-401, 1963.
HENDERSON, Roland George
1-63. (and FISCHER, W. A.) Applications of analytical methods to a single microdensitometer trace, in Astrogeologic studies--Annual progress report, Aug. 25, 1961 to Aug. 24, 1962, Pt. A, Lunar and planetary investigations: U. S. Geol. Survey open-file report, p. 51-57, 1963.
HENDRICKS, Ernest LeRoy
1-63. (and LANGBEIN, W. B., and TAYLOR, G. C., Jr.) New steps toward better data and investigation for water resources development, in U. S. Dept. State, Natural resources--Energy, water and river basin development: United Nations Conf. Application Sci. and Technology Benefit Less Developed Areas, Geneva, 1963, U. S. Papers, v. 1, p. 238-253, 1963.
HENDRICKSON, Gerth Edison
1-63. Notes on sources of ground-water recharge in the Lower Colorado River area as indicated by chemical character of the water [abs.]: Geol. Soc. America Spec. Paper 73, p. 170, 1963.
HERRICK, Stephen Marion
1-63. Subsurface study of Pleistocene deposits in Coastal Georgia [abs.]: Geol. Soc. America, Southeastern Sec., Ann. Mtg., Roanoke, Virginia, Apr. 1963, Program, p. 23, 1963.
2-63. Marginal sea of middle Eocene age in New Jersey [abs.]: Geol. Soc. America Spec. Paper 73, p. 10, 1963.
HERZ, Norman
1-62. Chemical composition of Precambrian pelitic rocks, Quadrilátero Ferrífero, Minas Gerais, Brazil: Art. 86 in U. S. Geol. Survey Prof. Paper 450-C, p. C75-C78, 1962.
2-62. Metamorfismo do Quadrilátero Ferrífero de Minas Gerais [abs.]: Acad. Brasileira Ciências Anais, v. 34, no. 4, p. xxxii, 1962. (Translation of abstract in Geol. Soc. America Spec. Paper 68, p. 196-197, 1962.)
HEWETT, Donnel Foster
1-63. (and FLEISCHER, Michael, and CONKLIN, N. M.) Deposits of the manganese oxides--Supplement: Econ. Geology, v. 58, no. 1, p. 1-51, 1963.
HEYL, Allen Van
1-62. (and BOZION, C. N.) Oxidized zinc deposits of the United States--Pt. 1. General geology: U. S. Geol. Survey Bull. 1135-A, p. A1-A52, 1962.
2-62. (and BROCK, M. R.) Zinc occurrence in the Serpent Mound structure of southern Ohio: Art. 148 in U. S. Geol. Survey Prof. Paper 450-D, p. D95-D97, 1962.
HIETANEN, Anna Martta
1-62. Metasomatic metamorphism in western Clearwater County, Idaho: U. S. Geol. Survey Prof. Paper 344-A, p. A1-A116, 1962.
2-62. Staurolite zone near the St. Joe River, Idaho: Art. 83 in U. S. Geol. Survey Prof. Paper 450-C, p. C69-C72, 1962.

HIETANEN, Anna Martta--Continued
1-63. Scapolite in the Belt Series northwest of the Idaho batholith [abs.]: Geol. Soc. America Spec.,Paper 73, p. 42-43, 1963.
HILL, David P.
1-63. (and PAKISER, L. C., Jr.) Gravity and crustal structure in the western Snake River Plain, Idaho [abs.]: Geol. Soc. America Spec. Paper 73, p. 86, 1963.
HILPERT, Lowell Sinclair
1-63. Regional and local stratigraphy of uranium-bearing rocks in the Ambrosia Lake-Laguna area, New Mexico: New Mexico Bur. Mines and Mineral Resources Mem. 15, p.,6-19, 1963.
HILTON, George Stockbridge
1-63. Water-resources reconnaissance in southeastern part of Honey Lake Valley, Lassen County, California: U. S. Geol. Survey Water-Supply Paper 1619-Z, p. Z1-Z8, 1963.
2-63. (and KLAUSING, R. L., and KUNKEL, Fred) Geology of the Terra Bella-Lost Hills area, San Joaquin Valley, California: U. S.,Geol. Survey open-file report, 64 p., 1963.
3-63. (and McCLELLAND, E. J., and KLAUSING, R. L., and KUNKEL, Fred) Hydrology of the Terra Bella-Lost Hills area, San Joaquin Valley, California: U. S. Geol. Survey open-file report, 74 p., 1963.
HINRICHS, Edgar Neal
1-62. (and McKAY, E. J.) Geologic map of the Plutonium Valley quadrangle, Nye and Lincoln Counties, Nevada: U. S. Geol. Survey Rept. TEI-825 (open-file report). (Report prepared for U. S. Atomic Energy Commission.)
HIRASHIMA, George T..
1-62. Effect of the Haiku tunnel on Kahaluu Stream, Oahu, Hawaii: Art. 108 in U. S. Geol. Survey Prof. Paper 450-C, p. C118-C120, 1962.
1-63. Aspects of ground-water storage and depletion along the Molokai Irrigation Tunnel, Molokai, Hawaii: Hawaii Div. Water and Land Devel. Circ. C20, 21 p., 1963. (Prepared by U. S. Geological Survey in coop. with Hawaii Division of Water and Land Development, Department of Land and Natural Resources.)
HITE, Robert James
1-3. Problems of joint development of potash and oil and gas in the Paradox basin, in Oil and gas possibilities of Utah, re-evaluated: Utah Geol. and Mineralog. Survey Bull. 54, p. 519-526, 1963.
HOARE, Joseph McCormick
1-62. (and LATHRAM, E. H.) Don John Miller (1919-1961): Am. Assoc. Petroleum Geologists Bull., v. 46, no. 8, p. 1534-1537, 1962.
HOFMANN, Walter
1-62. Problems in arid-land hydrology [abs.]: Am.,Geophys. Union Trans., v. 43, no. 4, p. 451, 1962.
1-63. (and RANTZ, S. E.) Floods of December 1955-January 1956 in the far western States--Pt. 2, Streamflow data: U. S. Geol. Survey Water-Supply Paper 1650-B, 580 p., 1963.
HOGENSON, Glenmore M.
1-62. Ground water in the East Portland area, Oregon: U. S. Geol.,Survey open-file report, 194 p., 1962.
HOGGATT, Richard E.
1-62. Low-flow characteristics of Indiana streams: Indiana Stream Pollution Control Board, 171 p., 1962. (Prepared by U. S. Geological Survey and State of Indiana.)
HOLMES, George William
1-61. (and LEWIS, C. R.) Glacial geology of the Mount Chamberlin area, Brooks Range, Alaska, in Raasch, G. O., ed., Geology of the Arctic: Internat. Symposium Arctic Geology, 1st, Calgary, Alberta, Jan. 1960, Proc., v. 2, Toronto, Ontario, Univ. Toronto Press, p. 848-864, 1961.
1-63. (and HOPKINS, D. M., and FOSTER, H. L.) Pingos in central Alaska [abs.]: Geol. Soc. America Spec. Paper 73, p. 173, 1963.
HOOD, James W.
1-62. (and HERRICK, E. H.) Water resources of the Three Rivers areas, Otero and Lincoln Counties, New Mexico: U. S. Geol. Survey open-file report, 125 p., 1962.
1-63. Saline ground water in the Roswell basin, Chaves and Eddy Counties, New Mexico, 1958-59: U. S. Geol. Survey Water Supply Paper 1539-M, p. M1-M46, 1963.
2-63. (and KISTER, L. R., Jr.) Saline-water resources of New Mexico: U. S. Geol. Survey Water-Supply Paper 1601, 70 p., 1963.
HOOVER, Linn
1-63. Geology of the Anlauf and Drain quadrangles, Douglas and Lane Counties, Oregon: U. S.,Geol. Survey Bull. 1122-D, p. D1-D62, 1963.
HOPKINS, David Moody
1-60. (and WAHRHAFTIG, C. A.) Annotated bibliography of English-language papers on the evolution of slopes under periglacial climates: Zeitschr. Geomorphologie (Berlin), Supplementband 1, p. 1-8, 1960.
HOPKINS, Herbert T.
1-63. The effect of oilfield brines on the potable ground water in the Upper Big Pitman Creek basin, Kentucky: Kentucky Geol. Survey, ser. 10, Rept. Inv. 4, 36 p., 1963. (Prepared in coop. with U. S. Geological Survey.)
HOPKINS, William B.
1-63. (and PETRI, L. R.) Geology and ground-water resources of the Lake Dakota plain area, South Dakota: U. S. Geol. Survey Water-Supply Paper 1539-T, p. T1-T68, 1963.
2-63. Geology and ground-water resources of the Scottsville area, Kentucky: U. S. Geol. Survey Water-Supply Paper 1528, 333 p., 1963.
3-63. (and TAYLOR, O. J.) Drainage and domestic water-supply investigations in the Milk River Unit, Blaine County, Montana: U. S. Geol. Survey open-file report, 112 p., 1963.
HOPSON, Clifford Andrae
1-62. (and WATERS, A. C., and BENDER, V. R., and RUBIN, Meyer) The latest eruptions from Mount Rainier volcano: Jour. Geology, v. 70, no. 6, p. 635-647; errata, v. 71, no. 1, p. 124, 1962.
HOSE, Richard Kenneth
1-63. (and SABLE, E. G., and HEDLUND, D. C.) Geology of the Lodiburg quadrangle, Kentucky: U.,S. Geol. Survey Geol. Quad. Map GQ-193, 1963. (Prepared in coop. with Kentucky Geological Survey.)
HOSTETLER, Paul Blair
1-62. Magnesium in natural bicarbonate-bearing waters [abs.]: Jour. Geophys. Research, v. 67, no. 9, p. 3566-3567, 1962.
1-63. The stability and surface energy of brucite in water at 25°C: Am. Jour. Sci., v. 261, no. 3, p..238-258, 1963.
HOTZ, Preston Enslow
1-63. (and JACKSON, E. D.) X-ray determinative curve for olivines of composition $Fo_{80-95}$ from stratiform and alpine-type peridotites: Art. 206 in U. S. Geol. Survey Prof. Paper 450-E, p. E101-E102, 1963.
HOUSER, Frederick Northrop
1-62. (and ECKEL, E. B.) Possible engineering uses of subsidence induced by contained underground nuclear explosions: Art. 66 in U. S. Geol. Survey Prof. Paper 450-C, p. C17-C18, 1962.
2-62. (and ECKEL, E. B.) Induced subsidence: GeoTimes, v. 7, no.,2, p. 14-15, 1962. (Reprinted from U. S. Geological Survey Prof. Paper 450-C.)
HOUSTON, Robert Stroud
1-63. (and MURPHY, J. F.) Titaniferous black sandstone deposits of Wyoming: Wyoming Geol. Survey Bull. 49, 120 p., 1963.
HUBBELL, David Wellington
1-62. (and HAUSHILD, W. L.) Discussion of "Dual channel stream monitor," by S. S.. Karaki, E. E. Gray, and J. Collins (Am. Soc. Civil Engineers Proc., v. 87, Jour. Hydraulics Div., no. HY 6, pt. 1, p. 1-16, 1961): Am. Soc. Civil Engineers Proc., v. 88, Jour. Hydraulics Div., no. HY 4, pt. 1, p. 287-291, 1962.
HUDDLE, John Warfield
1-62. (and ENGLUND, K. J.) Geology of the Kermit quadrangle in Kentucky: U. S. Geol. Survey [Geol. Quad. Map] GQ-178, 1962.
2-62. (and ENGLUND, K.,J.) Geology of the Varney quadrangle, Kentucky: U. S. Geol. Survey [Geol. Quad. Map] GQ-180, 1962.
1-63. (and LYONS, E. J., and SMITH, H. L., and FERM, J. C., and Harris, L. D., and ENGLUND, K. J.) Coal reserves of eastern Kentucky: U. S. Geol. Survey Bull. 1120, 247 p., 1963.
HUFF, Lyman Coleman
1-62. Using a Brunton compass and a spring wire for weighing small samples: Art. 103 in U. S. Geol. Survey Prof. Paper 450-C, p. C107-C108, 1962.
2-2. A geochemical study of copper deposits hidden beneath an alluvial cover in Pima County, Ariz. [abs.]: Mining Eng., v. 14, no. 11, p. 65, 1962.
HUFFMAN, Claude, Jr.
1-63. (and LIPP, H. H., and RADER, L. F., Jr.) Spectrophotometric determination of micro quantities of zinc in rocks: Geochim. et Cosmochim. Acta, v. 27, no. 3, p. 209-215, 1963.
2-63. Ion-exchange separation and spectrophotometric determination of cadmium: Art. 214 in U. S. Geol. Survey Prof. Paper 450-E, p. E126-E127, 1963.
HUGHES, Gilbert H.
1-63. A study of the evaporation from Salton Sea, California: U. S. Geol. Survey open-file report, 14 p., 1963.
HUGHES, Leon S.
1-62. (and SHELBY, Wanda) Chemical composition of Texas surface waters, 1960: Texas Water Comm. Bull. 6215, 102 p., 1962. (Prepared in coop. with U. S. Geological Survey and others.)
HUNT, Charles Butler
1-62. Tectonic framework of southwestern United States and possible continental rifting, in Backbone of the Americas: Am. Assoc. Petroleum Geologists Mem. 2, p. 130-139, 1963.
HYDEN, Harold Julius
1-62. (and DANILCHIK, Walter) Uranium in some rocks of Pennsylvanian age in Oklahoma, Kansas, and Missouri: U. S. Geol.,Survey Bull. 1147-B, p. B1-B79, 1962.
1-63. Geologic map of Cooper Cove and Dutton Creek oil fields and vicinity, Albany and Carbon Counties, Wyoming: U. S. Geol. Survey open-file report, 1963.
IMLAY, Ralph Willard
1-63. Jurassic fossils from southern California: Jour. Paleontology, v. 37, no. 1, p. 97-107, 1963.
INGERSON, Earl
1-61. (and MACKIN, J. H.) Derivation of ore-forming fluids in the Iron Springs district, Utah, in Fiziko-khimicheskie problemy formirovaniya gornykh porod i rud, V. 1: Moscow, Akad.,Nauk SSSR, Inst. Geologii Rudnykh Mestorozhdenii, Petrografii, Mineralogii i Geokhimii, p. 138-148, 1961.
INGRAM, Blanche L.
1-63. Spectrophotometric determination of fluorine with thoron: Art. 216 in U. S. Geol. Survey Prof. Paper 450-E, p. E130, 1963.
IRELAN, Burdge
1-63. (and MENDIETA, H. B.) Chemical quality of surface waters in the Brazos River basin in Texas: U. S. Geol. Survey open-file report, 125 p., 1963.
IRVING, Earl Montgomery
1-61. Geologic map of the Philippine Islands, in United Nations, Econ. Comm. Asia and Far East (ECAFE), Geological map of Asia and the Far East, Sheet 6, 1961.

IRWIN, William Porter
1-62. (and LIPMAN, P. W.) A regional ultramafic sheet in eastern Klamath Mountains, California: Art. 67 in U. S. Geol. Survey Prof. Paper 450-C, p. C18-C21, 1962.
ISBISTER, John
1-63. Records of wells and related hydrologic data in northeastern Nassau County, New York: U. S. Geol. Survey open-ile report, 38 p., 1963.
2-63. Relation of fresh water to salt water at Centre Island, Nassau County, New York: Art. 226 in U. S. Geol. Survey Prof. Paper 450-E, p. E154-E156, 1963.
IZETT, Glen A.
1-63. Geologic map of the Storm Hill quadrangle, Wyoming: U. S. Geol. Survey Misc. Geol. Inv. Map I-372, 1963. (Prepared in coop. with U. S. Atomic Energy Commission.)
2-63. (and TAYLOR, R. B., and HOOVER, D. L.) Windy Gap Volcanic Member of the Middle Park Formation, Middle Park, Colorado: Art. 189 in U. S. Geol. Survey Prof. Paper 450-E, p. E36-E39, 1963.
JACKSON, Roy O.
1-3. (and BOGUE, R. G., and BROWN, G. F., and GIERHART, R. D.) Geology of the southern Najd quadrangle, Kingdom of Saudi Arabia: U. S. Geol. Survey Misc. Geol. Inv. Map I-211 A, 1963.
JAMES, Harold Lloyd
1-62. (and CLAYTON, R. N.) Oxygen isotope fractionation in metamorphosed iron formations of the Lake Superior region and in other iron-rich rocks, in Petrologic studies--A volume in honor of A. F. Buddington: New York, New York, Geol. Soc. America, p. 217-239, 1962.
2-62. (and WIER, K. L.) Geologic map of iron deposits near Copper Mountain, Madison County, Montana: U. S. Geol. Survey open-file report, 1962.
3-62. (and WIER, K. L.) Magnetic and geologic map of iron deposits near Copper Mountain, Madison County, Montana: U. S. Geol. Survey open-file report, 1962.
JANZER, Victor J.
1-62. (and GOLDBERG, M. C., and ANGELO, C. G., and BEETEM, W. A.) Summary of distribution coefficient data for fission products between ground water and rocks from Project Gnome: U. S. Atomic Energy Comm. Rept. PNE-130F, p. 138-159, 1962. (Report prepared for U. S. Atomic Energy Commission by U. S. Geological Survey for Project Gnome.)
JENKINS, Clifford T.
1-63. Floods on St. Vrain and Lefthand Creeks at Longmont, Colorado: U. S. Geol. Survey open-file report, 32 p., 1963.
JENKINS, Edward D.
1-63. (and MOULDER, E. A.) Ground-water technology and litigation problems: Am. Soc. Civil Engineers Proc., v. 89, Jour. Irrigation and Drainage Div., no. IR 2, pt. 1, p. 75-76, 1963. (Reply to discussion of paper, same journal, v. 88, no. IR 2, pt. 1, p. 21-32, 1962.)
JENSEN, Hans M.
1-62. Geology and occurrence of ground water near Bowbells, Burke and Ward Counties, North Dakota: North Dakota State Water Conserv. Comm., North Dakota Ground-Water Study 42, 65 p., 1962. (Prepared by U. S. Geological Survey in coop. with North Dakota State Water Conservation Commission and North Dakota Geological Survey.)
2-62. (and BRADLEY, Edward) Ground water near Hoople, Walsh and Pembina Counties, North Dakota: North Dakota State Water Conserv. Comm., North Dakota Ground-Water Study 49, 19 p., 1962. (Prepared by U. S. Geological Survey in coop. with North Dakota State Water Conservation Commission and North Dakota Geological Survey.)
JESPERSEN, Anna
1-63. (and GRISCOM, Andrew) Aeromagnetic interpretation of the geology of the Greenwood Lake and Sloatsburg quadrangles, New York and New Jersey: U. S. Geol. Survey Geophys. Inv. Map GP-311, 1963.
JOBIN, Daniel Alfred
1-62. Relation of the transmissive character of the sedimentary rocks of the Colorado Plateau to the distribution of uranium deposits: U.,S. Geol. Survey Bull. 1124, 151 p., 1962.
JOERNS, John O.
1-62. Investigations of sources of natural pollution, Wichita River basin above Lake Kemp, Texas, 1951-57: U. S. Geol. Survey open-file report, 16 p., 1962.
JOESTING, Henry Rochambeau
1-62. (and CASE, J. E.) Regional geophysical studies in Salt Valley-Cisco area, Utah and Colorado: Am. Assoc. Petroleum Geologists Bull., v. 46, no. 10, p.,1879-1889, 1962.
2-62. (and CASE, J. E., and PLOUFF, D. F.) Regional gravity survey of the Moab-Needles area, Grand, San Juan, Emery, Garfield, and Wayne Counties, Utah: U.,S. Geol. Survey open-file report, 15 p., 1962.
1-63. (and CASE, J. E.) Principal facts for gravity stations in the La Sal Mountains area, Grand and San Juan Counties, Utah, and Mesa and Montrose Counties, Colorado: U. S.,Geol. Survey open-file report, 17 p., 1963.
2-63. (and CASE, J. E.) Principal facts for gravity stations in the Uravan area, Mesa, Montrose, and San Miguel Counties, Colorado: U.,S. Geol. Survey open-file report, 19 p., 1963.
3-63. (and CASE, J. E., and PLOUFF, D. F.) Principal facts for gravity stations in the Moab-Needles area, Grand and San Juan Counties, Utah, and for the Lisbon Valley area, San Juan County, Utah, and Montrose and San Miguel Counties, Colorado: U. S. Geol. Survey open-file report, 21 p. of tables, 1963.
JOHNSON, Alfred Massey Fisher
1-62. (and RANDOLPH, W. J.) Floods on Chattanooga Creek at Chattanooga, Tennessee: U. S.,Geol. Survey open-file report, 46 p., 1962.
JOHNSON, Arnold Ivan
1-63. A field method for measurement of infiltration: U. S. Geol. Survey Water-Supply Paper 1544-F, p. F1-F27, 1963.
2-63. Reconnaissance of several projects in southeastern Idaho: U. S. Geol. Survey open-file report, 165 p., 1963.
JOHNSON, Arthur
1-63. Glacier observations, Glacier National Park, Montana, 1962: U. S. Geol. Survey open-file report, 30 p., 1963.
JOHNSON, Frederick A.
1-62. Some recent climatic anomalies and their possible effect on hydrologic studies [abs.]: Jour. Geophys. Research, v. 67, no. 9, p. 3569, 1962.
JOHNSON, Jesse Harlan
1-61. The use of calcareous algae in correlating Cenozoic deposits of the western Pacific area: Pacific Sci. Cong., 9th, Bangkok, Thailand, 1957, Proc., v. 12, Geology and Geophysics, p. 282-286, 1961 [1962].
JOHNSON, Karl Elwood
1-60. (and MASON, R. A., and DeLUCA, F. A.) Ground-water map of the Oneco quadrangle, Connecticut-Rhode Island, showing water-bearing formations and related ground-water data: Rhode Island and Providence Plantations Water Resources Coordinating Board Ground-Water Map GWM 10, 1960. (Prepared in coop. with U. S. Geological Survey and Connecticut Water Resources Commission.)
1-62. Ground-water map of the Rhode Island parts of the Attleboro, Blackstone, Franklin, Oxford, and Uxbridge quadrangles, showing water-bearing formations and related ground-water data: Rhode Island and Providence Plantations Water Resources Coordinating Board Ground-Water Map GWM 19, 1962. (Prepared in coop. with U. S. Geological Survey.)
JOHNSON, Robert Francis
1-62. Geology and ore deposits of the Cachoeira do Campo, Dom Bosco, and Ouro Branco quadrangles, Minas Gerais, Brazil: U. S. Geol. Survey Prof. Paper 341-B, p. B1-B39, 1962.
JOHNSON, Robert William, Jr.
1-62. Mineral commodities framework of the southeastern U. S. and its role in future industrialization in the region [abs.]: Mining Eng., v. 14, no. 7, p. 40, 1962.
2-62. Some geologic factors bearing on the interpretation of geophysical anomalies [abs.]: Mining Eng., v. 14, no. 7, p. 40, 1962.
1-63. (and KING, E. R., and HAWKINS, D. R.) Aeromagnetic map of the Chinook quadrangle, Blaine County, Montana: U. S. Geol. Survey Geophys. Inv. Map GP-383, 1963.
2-63. (and KING, E. R., and PAGE, E. E.) Aeromagnetic map of part of the Cleveland quadrangle, Blaine County, Montana: U. S. Geol. Survey Geophys. Inv. Map GP-385, 1963.
3-63. (and KING, E. R., and PETRAFESO, F. A.) Aeromagnetic map of part of the Lloyd quadrangle, Blaine and Hill Counties, Montana: U. S. Geol. Survey Geophys. Inv. Map GP-384, 1963.
4-63. (and KING, E. R., and LONG, C. L.) Aeromagnetic map of the Yantic quadrangle, Blaine and Hill Counties, Montana: U. S. Geol. Survey Geophys. Inv.,Map GP-382, 1963.
5-63. (and WATKINS, J. S., Jr.) Aeromagnetic map of Staunton and vicinity, Virginia: U. S. Geol. Survey Geophys. Inv. Map GP-414, 1963.
JOHNSON, Ross Byron
1-62. The Ralston Creek(?) Formation of Late Jurassic age in the Raton Mesa region and Huerfano Park, south-central Colorado: Art. 77 in U. S. Geol. Survey Prof. Paper 450-C, p. C49-C54, 1962.
JOHNSTON, John Edward
1-62. Geology of the Lenox quadrangle, Kentucky: U. S. Geol. Survey Geol. Quad. Map GQ-181, 1962. (Prepared in coop. with Kentucky Geological Survey.)
JOHNSTON, Paul McKelvey
1-62. Geology and ground-water resources of the Fairfax quadrangle, Virginia: U. S. Geol. Survey Water-Supply Paper 1539-L, p. L1-L61, 1962.
JOHNSTON, Richard Henry
1-62. Water-bearing characteristics of the Lockport Dolomite near Niagara Falls, New York: Art. 110 in U. S. Geol. Survey Prof. Paper 450-C, p. C123-C125, 1962.
JOHNSTON, William Drumm, Jr.
1-63. The role of national geological surveys in mineral resources development, in U. S. Dept. State, Natural resources--Minerals and mining, mapping and geodetic control: United Nations Conf. Application Sci. and Technology Benefit Less Developed Areas, Geneva, 1963, U. S. Papers, v. 2, p. 18-22, 1963.
JONES, Benjamin L.
1-62. (and UNGER, D. G.) Measuring effects of conservation: Jour. Soil and Water Conserv., v.,17, no. 4, p. 172-174, 1962.
JONES, Blair Francis
1-62. Stability of burkeite and its significance in lacustrine evaporites [abs.]: Jour. Geophys. Research, v. 67, no. 9, p. 3569-3570, 1962.
JONES, Charles L.
1-63. Geologic and petrographic features of Upper Permian evaporites in southeastern New Mexico [abs.]: Geol. Soc. America Spec. Paper 73, p. 276, 1963.
2-63. Halite and associated rocks in the salt anticline region, Utah and Colorado [abs.]: Geol. Soc. America Spec. Paper 73, p. 275-276, 1963.
JONES, David Lawrence
1-63. Stratigraphy of Cretaceous rocks of the upper Chitina Valley, Alaska [abs.]: Geol. Soc. America Spec. Paper 73, p. 43, 1963.
JONES, Paul Hastings
1-62. (and SCHMALZ, B. L.) Distribution of radionuclides in groundwater at the National Reactor Testing Station, with particular reference to tritium [abs.]: Jour. Geophys. Research, v. 67, no.,9, p. 3570-3571, 1962.

JONES, Paul Hastings--Continued
2-62. (and SCHUTER, Eugene) Hydrology of radioactive waste disposal in the MTR-ETR area, National Reactor Testing Station, Idaho: Art. 106 in U. S. Geol. Survey Prof. Paper 450-C, p. C113-C116, 1962.
JONES, William Rich
1-63. Preliminary geologic map of Fort Bayard quadrangle, Grant County, New Mexico: U. S. Geol. Survey open-file report, 1963.
JORDAN, Donald G.
1-62. Ground water contamination in Indiana: Am. Water Works Assoc. Jour., v. 54, no. 10, p. 1213-1220, 1962.
KAMMERER, John Craig
1-62. (and BALDWIN, H. L., Jr.) Water problems in the Springfield-Holyoke area, Massachusetts--A layman's look at water in a metropolitan area: U. S. Geol. Survey Water-Supply Paper 1670, 68 p., 1962.
KANE, Martin Francis
1-62. A comprehensive system of terrain corrections using a digital computer: Geophysics, v. 27, no. 4, p. 455-462, 1962.
1-63. (and BROMERY, R. W., and FRISCHKNECHT, F. C.) Exploratory geophysical traverses in the Oakfield Hills area, Smyrna Mills quadrangle, Maine: U. S. Geol. Survey open-file report, 9 p., 1963.
2-63. Precambrian rock densities and isostatic processes in Clark County, Nevada [abs.]: Geol. Soc. America Spec. Paper 73, p. 184, 1963.
KAYE, Clifford Alan
1-62. Early postglacial beavers in southeastern New England: Science, v. 138, no. 3543, p. 906-907, 1962.
2-62. Shore-erosion study of the coasts of Georgia and northwest Florida: U. S. Geol. Survey open-file report, 74 p., 1962.
3-62. (and SCHAFER, J. P.) The Charlestown moraine and the retreat of the last ice sheet in southern Rhode Island: Friends Pleistocene, 25th Ann. Reunion, Kingston, Rhode Island, May 19-20, 1962, Itinerary, 15 p., 1962.
KEECH, Charles Franklin
1-62. Geology and hydrology of the site of the Hallam Nuclear Power Facility, Nebraska: U. S. Geol. Survey Bulletin 1133-B, p. B1-B51, 1962.
KEEFER, William Richard
1-63. (and LOVE, J. D.) Laramide vertical movements in central Wyoming: Wyoming Univ. Dept. Geology Contr. Geology, S. H. Knight Issue, v. 2, no. 1, p. 47-54, 1963.
KELLER, Frank J.
1-62. Effect of urban growth on sediment discharge, Northwest Branch Anacostia River basin, Maryland: Art. 113 in U. S. Geol. Survey Prof. Paper 450-C, p.,C129-C131, 1962.
KELLER, Fred, Jr.
1-63. (and HENDERSON, J. R., and others) Aeromagnetic map of the Magnet Cove area, Hot Spring County, Arkansas: U. S. Geol. Survey Geophys. Inv. Map GP-409, 1963.
2-63. (and HENDERSON, J. R.) Aeromagnetic map of part of the Tri-State mining district, Kansas, Missouri, and Oklahoma: U. S. Geol. Survey Geophys. Inv. Map GP-427, 1963.
KELLER, George V.
1-63. Electrical properties of the lower crust and upper mantle [abs.]: Am. Geophys. Union Trans., v. 44, no. 1, p. 97, 1963.
KELLER, Walter David
1-62. Clay minerals in the Morrison Formation of the Colorado Plateau: U. S. Geol. Survey Bull. 1150, 90 p., 1962.
KENNEDY, Daniel
1-63. Discussion of "Civil requirements for topographic maps," by R. H. Lyddan (Am. Soc. Civil Engineers Proc., v. 88, Jour. Surveying and Mapping Div., no. SU 1, p. 1-6, 1962): Am. Soc. Civil Engineers Proc., v. 89, Jour. Surveying and Mapping Div., no. SU 2, p. 87, 1963.
2-63. Discussion of "Large-scale mapping of Lake Powell [Ariz.-Utah]," by C. D. Gessel and D. H. Rutledge (Am. Soc. Civil Engineers Proc., v. 88, Jour. Surveying and Mapping Div., no. SU 1, p. 17-27, 1962): Am. Soc. Civil Engineers Proc., v. 89, Jour. Surveying and Mapping Div., no. SU 2, p. 91, 1963.
3-63. Discussion of "Military requirements for topographic maps," by F. O. Diercks (Am. Soc. Civil Engineers Proc., v. 88, Jour. Surveying and Mapping Div., no. SU 1, p. 7-15, 1962): Am. Soc. Civil Engineers Proc., v. 89, Jour. Surveying and Mapping Div., no. SU 2, p. 89, 1963.
KENTUCKY GEOLOGICAL SURVEY
1-63. Status of Kentucky areal geologic mapping program: Lexington, 1 sheet, 1963. (Prepared in coop. with U. S. Geological Survey.)
KETNER, Keith Brindley
1-62. Geology of the Scottsville quadrangle, Kentucky: U. S. Geol. Survey Geol. Quad. Map GQ-184, 1962. (Prepared in coop. with Kentucky Geological Survey.)
KHAN, Nur M.
1-63. (and REINEMUND, J. A.) A cooperative mineral exploration and development program in Pakistan, in U. S. Dept. State, Natural resources--Minerals and mining, mapping and geodetic control: United Nations Conf. Application Sci. and Technology Benefit Less Developed Areas, Geneva, 1963, U. S. Papers, v. 2, p. 71-89, 1963.
KIILSGAARD, Thor H.
1-63. (and HEYL, A. V., and BROCK, M. R.) The Crooked Creek disturbance, southeast Missouri: Art. 183 in U. S. Geol. Survey Prof. Paper 450-E, p. E14-E19, 1963.
KILBURN, Chabot
1-62. (and PRICE, W. E., Jr., and MULL, D. S.) Availability of ground water in Bell, Clay, Jackson, Knox, Laurel, Leslie, McCreary, Owsley, Rockcastle, and Whitley Counties, Kentucky--Sheet 1, Geologic map; sheet 2, Ground water; sheet 3, Generalized columnar section: U. S. Geol. Survey Hydrol. Inv. Atlas HA-38, 1962.
KILBURN, Chabot--Continued
2-62. (and WHITMAN, H. M.) Water levels in southwestern Louisiana, April 1960 to April 1961, with a discussion of water-level trends from 1950 to 1960: Louisiana Geol. Survey Water Resources Pamph. 11, 21 p., 1962. (Prepared in coop. with U. S. Geological Survey.)
KILKENNY, John Edward
1-63. (and FACKLER, J. H.) Geology of the San Miguel dome, in Am. Assoc. Petroleum Geologists and Soc. Econ. Paleontologists and Mineralogists, Pacific Secs., Guidebook to the geology of Salinas Valley and the San Andreas fault, Ann. Spring Field Trip, May 1963, p.,88-91, 1963.
KIMREY, Joel O.
1-62. Delineation of phosphorite deposits with gamma-ray logs in Beaufort County, N. C. [abs.]: Econ. Geology, v. 57, no. 6, p. 1015, 1962.
1-63. Delineation of phosphorite deposits with gamma-ray logs in Beaufort County, North Carolina [abs.]: Geol. Soc. America Spec. Paper 73, p.,186, 1963.
KING, Elizabeth Raymond
1-63. (and ZIETZ, Isidore and ALLDREDGE, L. R.) Investigation of the Arctic Ocean basin by airborne magnetometer [abs.]: Soc. Explor. Geophysicists Yearbook 1963, p. 188-189, 1963.
KING, Philip Burke
1-63. Further thoughts on tectonic framework of southeastern United States [abs.]: Geol. Soc. America, Southeastern Sec., Ann. Mtg., Roanoke, Virginia, Apr. 1963, Program, p. 13, 1963.
KINKEL, Arthur Rudolph, Jr.
1-61. Commonwealth delegates impressed by copperbelt mines: Mining World, v. 23, no. 9, p. 34-35, 1961.
1-62. Observations on the pyrite deposits of the Huelva district, Spain, and their relation to volcanism: Econ. Geology, v. 57, no. 7, p. 1071-1080, 1962.
2-62. The Ore Knob massive sulfide copper deposit, North Carolina--An example of recrystallized ore: Econ. Geology, v. 57, no. 7, p. 1116-1121, 1962.
KIRKPATRICK, George A.
1-62. (and McCABE, J. A.) Use of regionalized flood-frequency curves in adjusting flow-duration curves: Art. 174 in U. S. Geol. Survey Prof. Paper 450-D, p. D179-D181, 1962.
KISTER, Lester Ray, Jr.
1-61. (and HARDT, W. F.) Correlation of ground-water quality with different sediment types, lower Santa Cruz basin, Arizona: Arizona Geol. Soc. Digest, v. 4, p. 79-85, 1961.
1-63. (and HATCHETT, J. L.) Geohydrologic data in the Navajo and Hopi Indian Reservations, Arizona, New Mexico, and Utah--Pt. 2, Selected chemical analyses of the ground water: U. S. Geol. Survey open-file report, 7 p., 1963..
2-63. (and HATCHETT, J. L.) Geohydrologic data in the Navajo and Hopi Indian Reservations, Arizona, New Mexico, and Utah--Pt. 2, Selected chemical analyses of the ground water: Arizona State Land Dept. Water Resources Rept. 12-B, 58 p., 1963. (Prepared by U. S. Geological Survey in coop. with Bureau of Indian Affairs and Navajo Tribe.)
KISTLER, Ronald W.
1-63. The Mono craters caldera [California] [abs.]: Am. Geophys. Union Trans., v. 44, no. 1, p. 113, 1963.
KLEIN, Howard
1-62. (and SCHROEDER, M. C., and LICHTLER, W. F.) Geology and groundwater resources of Glades and Hendry Counties, Florida: U. S. Geol. Survey open-file report, 162 p., 1962.
KLEINHAMPL, Frank Joseph
1-62. Botanical prospecting for uranium on South Elk Ridge, San Juan County, Utah: U. S. Geol. Survey Bull. 1085-D, p. 105-188, 1962.
KLEMIC, Harry
1-63. Geology of the Rhoda quadrangle, Kentucky: U. S. Geol. Survey Geol. Quad.,Map GQ-219, 1963. (Prepared in coop. with Kentucky Geological Survey.)
KNOPF, Eleanora Bliss
1-62. Stratigraphy and structure of the Stissing Mountain area, Dutchess County, New York: Stanford Univ. Pubs. Geol. Sci., v. 7, no. 1, 55 p., 1962.
KNORRING, Oleg von
1-63. (and MROSE, M. E.) Westgrenite and waylandite, two new bismuth minerals from Uganda [abs.]: Geol. Soc. America Spec..Paper 73, p. 256-257, 1963.
KNOX, Arthur Stewart
1-62. Pollen from the Pleistocene terrace deposits of Washington, D. C. [abs.]: Pollen et Spores (Paris), v. 4, no. 2, p. 357-358, 1962.
KOBERG, Gordon E.
1-63. (and CRUSE, R. R., and SHREWSBURY, C. L.) Evaporation control research, 1959-60: U. S. Geol. Survey Water-Supply Paper 1692, 55 p., 1963.
KOCZY, Friedrich Frans
1-62. (and ROSHOLT, J. N., Jr.) Radioactivity in oceanography, in Nuclear radiation in geophysics, H. Israël, and A. Krebs, A., ed.: New York, New York, Acad. Press Inc., p. 18-46, 1962.
KOHOUT, Francis Anthony
1-63. (and HOY, N. D.) Some aspects of sampling salty ground water in coastal aquifers: Ground Water, Jour. Natl. Water Well Assoc., v. 1, no. 1, p. 28-32, 43, 1963.
KONISHI, Kenji
1-63. (and EPIS, R. C.) Some early Cretaceous calcareous algae from Cochise County, Arizona: Micropaleontology, v. 8, no. 1, p. 67-76, 1962.

KONIZESKI, Richard L.
1-62. (and McMURTREY, R. G., and BRIETKRIETZ, Alex) Preliminary report on the geology and ground-water resources of the southern part of the Deer Lodge Valley, Montana: Montana Bur. Mines and Geology Bull. 31, 24 p., 1962. (Prepared by U. S. Geological Survey in coop. with Montana Bureau Mines and Geology.)

KOSCHMANN, Albert Herbert
1-62. The historical pattern of mineral exploitation in Colorado, in Minerals and energy--Problems, practices, and goals, Western Resources Conference, 1962: Colorado School Mines Quart., v. 57, no. 4, pt. 1, p. 7-25, 1962 [1963].
1-63. Preliminary report on the Jones-Boy Scout and the Moss-Dryden molybdenum prospects near Hollister, North Carolina: U. S. Geol. Survey open-file report, 12 p., 1963.

KOTEFF, Carl
1-62. (and COTTON, J. E.) Preliminary results of recent deep drilling on Cape Cod, Massachusetts: Science, v. 137, no. 3523, p. 34, 1962.

KRICHEVSKY, Micah I.
1-61. (and FRIEDMAN, Irving, and NEWELL, M. F., and SISLER, F. D.) Deuterium fractionation during molecular hydrogen formation in a marine pseudomonad: Jour. Biol. Chemistry, v. 236, no. 9, p. 2520-2525, 1961.

KRIEGER, Robert Albert
1-61. Ground water contamination in the Greensburg oil field, Kentucky, in U. S. Public Health Service, 1961 Symposium on Ground-Water Contamination: Robert A. Taft Sanitary Eng. Center Tech. Rept. W61-5, p. 91-97, 1961.
1-62. The chemistry of saline waters [abs.]: Water Well Jour., v. 16, no. 10, p. 46-47, 1962; Ground Water, Jour. Natl. Water Well Assoc., v. 1, no. 2, p. 36, 1963.

KRINSLEY, Daniel Bernard
1-62. Limnology, in Needleman, S. M., ed., Arctic earth science investigations, Centrum Sø, Northeast Greenland, 1960: U. S. Air Force Cambridge Research Labs. Geophysics Research Directorate Air Force Surveys Geophysics, no. 138 (AFCRL-62-695), p. 47-55, 1962.

KUNKEL, Fred
1-63. Hydrologic and geologic reconnaissance of Pinto basin, Joshua Tree National Monument, Riverside County, California: U. S. Geol. Survey Water-Supply Paper 1475-O, p. 537-561, 1963.
2-63. Electric logs--A training aid: U. S. Geol. Survey open-file report, 6 p., 1963.

KUNKLE, George R.
1-63. Discussion of "Baseflow recession analysis for comparison of drainage basins and geology," by W. G. Knisel, Jr. (Jour. Geophys. Research, v. 68, no. 12, p. 3649-3653, 1963): Jour. Geophys. Research, v. 68, no. 12, p. 3654, 1963.

KUPFER, Donald Harry
1-62. (and BASSETT, A. M.) Geologic reconnaissance map of part of the southeastern Mojave Desert, California: U. S. Geol. Survey Mineral Inv. Field Studies Map MF-205, 1962.
1-63. Geology of the Calamity Peak area, Custer County, South Dakota: U. S. Geol. Survey Bull. 1142-E, p. E1-E23, 1963.

LACHENBRUCH, Arthur Herold
1-61. (and GREENE, G. W., and MARSHALL, B. V.) Preliminary results of geothermal studies at Ogotoruk Creek, AEC Project Chariot Test Site, northwestern Alaska [abs.]: Alaska Oil and Gas Yearbook 1960, p. 85, 1961.
1-62. Mechanics of thermal contraction cracks and ice-wedge polygons in permafrost: Geol. Soc. America Spec. Paper 70, 69 p., 1962.
2-62. (and BREWER, M. C., and GREENE, G. W., and MARSHALL, B. V.) Temperature in permafrost, in Herzfeld, C. M., ed.-in-chief, Temperature, its measurement and control in science and industry, V. 3--Pt. 1, Basic concepts, standards and methods, ed. by F. G. Brickwedde: New York, New York, Reinhold Publishing Co., p. 791-803, 1962.
1-63. Geothermal aspects of permafrost terrane [abs.]: Geol. Soc. America Spec. Paper 73, p. 192, 1963.

LADD, Harry Stephen
1-62. Pacific island terraces: Geog. Rev., v. 52, no. 4, p. 605-607, 1962.
2-62. Origin of the Pacific island molluscan fauna, in White, J. F., ed., Study of the earth--Readings in geological science: Englewood Cliffs, New Jersey, Prentice-Hall, Inc., p. 321-335, 1962.

LaFEHR, Thomas R.
1-62. (and PAKISER, L. C.) Gravity, volcanism, and crustal deformation in the eastern Snake River Plain, Idaho: Art. 141 in U. S. Geol. Survey Prof. Paper 450-D, p. D76-D78, 1962.

LAINE, Leo L.
1-63. (and MURPHY, J. J.) Surface water of Beaver Creek basin in south-central Oklahoma: U. S. Geol. Survey open-file report, 22 p., 1963.

LAKIN, Hubert William
1-63. (and WARD, F. N.) Analytical methods used in geochemical prospecting by the U. S. Geological Survey, AGI Data Sheet 41: GeoTimes, v. 7, no. 7, p. 29-30, 1963.
2-63. (and THOMPSON, C. E.) Effect of copper on the precipitation of tellurium with hypophosphorus acid using selenium or gold as a collector: Art. 215 in U. S. Geol. Survey Prof. Paper 450-E, p. E128-E129, 1963.

LAMAR, William Luther
1-63. (and GOERLITZ, D. F.) Characterization of carboxylic acids in unpolluted streams by gas chromatography: Am. Assoc. Water Works Jour., v. 55, no. 6, p. 797-802, 1963.

LAMBERT, T. William
1-63. (and BROWN, R. F.) Availability of ground water in Caldwell, Christian, Crittenden, Livingston, Lyon, Todd, and Trigg Counties, Kentucky--Sheet 1, Geologic map; sheet 2, Ground water; sheet 3, Generalized columnar section: U. S. Geol. Survey Hydrol. Inv. Atlas HA-34, 1963. (Prepared in coop. with Kentucky Geological Survey and Kentucky Dept. Economic Development.)

LAMKE, Robert D.
1-62. Surface Water Branch: Nevada Dept. Conserv. and Nat. Resources Humboldt River Research Proj., 3d Prog. Rept., p. 14-16, 1962.

LaMOREAUX, Philip Elmer
1-59. (and TOULMIN, L. D., Jr.) Geology and ground-water resources of Wilcox County, Alabama: Alabama Geol. Survey County Rept. 4, 280 p., 1959 [1960].

LANDEN, David
1-63. Photo interpretation of ice and snow features in the Antarctic: Internat. Archives Photogrammetry, Symposium on photo interpretation, Delft, Netherlands, Sept. 1962, Trans., v. 14, p. 366-373, 1963.

LANG, Joseph Winford
1-62. Typical methods of well construction in Mississippi: Mississippi Board Water Commissioners, Mississippi Water News, v. 1, no. 49, p. 1, 3-4, 1962.

LANGBEIN, Walter B.
1-62. Surface water (including sedimentation), in Problems of the arid zone--Proceedings of the Paris Symposium [May 11-18, 1960]: United Nations Educ., Sci. and Cultural Organization Arid Zone Research, v. 18, p. 3-22, 1962.

LARAWAY, William H.
1-62. (and HOUSER, F. N.) Outline of geology of the U12j and U12j.01 tunnels, Nevada Test Site: U. S. Geol. Survey Rept. TEI-828, open-file report, 12 p., 1962. (Report prepared for U. S. Atomic Energy Commission.)

LARSEN, Esper Signius, Jr.
1-62. (and MEYROWITZ, Robert) Immersion media for measurement of index of refraction, in International tables for X-ray crystallography--V. 3, Physical and chemical tables: Birmingham, England, Internat. Union Crystallography, p. 14-16, 1962.

LaSALA, Albert Mario, Jr.
1-60. (and JOHNSON, K. E.) Ground-water map of the Quonochontaug quadrangle, Rhode Island, showing water-bearing formations and related ground-water data: Rhode Island and Providence Plantations Water Resources Coordinating Board Ground-Water Map GWM 11, 1960. (Prepared in coop. with U. S. Geological Survey.)
1-62. Geology and ground-water resources of the Bristol-Plainville-Southington area, Connecticut: U. S. Geol. Survey open-file report, 180 p., 1962.

LAURENCE, Robert Abraham
1-63. Rediscovery of the Murray Gap fossil locality, Blount County, Tennessee [abs.]: Geol. Soc. America, Southeastern Sec. Ann. Mtg., Roanoke, Virginia, Apr. 1963, Program, p. 26-27, 1963.
2-63. Rediscovery of the Murray Gap fossil locality, Blount County, Tennessee [abs.]: Tennessee Acad. Sci. Jour., v. 38, no. 2, p. 64, 1963.

LAWRENCE, Fred Forrest
1-63. (and NORDEEN, C. E., and PUMPHREY, H. L.) History of land classification relating to waterpower and storage sites: U. S. Geol. Survey Circ. 400, 6 p., revised 1963. (Originally published 1957.)

LEE, Donald Edward
1-62. (and BASTRON, Harry) Allanite from the Mount Wheeler area, White Pine County, Nevada: Am. Mineralogist, v. 47, nos. 11-12, p. 1327-1331, 1962.
1-63. (and ERD, R. C.) Phenakite from the Mount Wheeler area, Snake Range, White Pine County, Nevada: Am. Mineralogist, v. 48, nos. 1-2, p. 189-193, 1963.

LeGRAND, Harry Elwood
1-62. Geology and ground-water resources of the Macon area, Georgia: Georgia Geol. Survey Bull. 72, 68 p., 1962. (Prepared by U. S. Geological Survey in coop. with Georgia Dept. Mines, Mining and Geology.)
2-62. Perspective on problems of hydrogeology: Geol. Soc. America Bull., v. 73, no. 9, p. 1147-1151, 1962.

LEMMON, Dwight Moulton
1-62. (and TWETO, O. L.) Tungsten in the United States, exclusive of Alaska and Hawaii: U. S. Geol. Survey Mineral Inv. Resource Map MR-25, 1962.

LENDO, Alexander C.
1-63. (and McCALL, J. E.) Surface-water supply of New Jersey--Streamflow records, October 1955 to September 1960: U. S. Geol. Survey open-file report, 438 p., 1963.

LEO, Gerhard William
1-63. Cordierite paragenesis in some pelitic rocks of the Serra de Jacobina, Bahía, Brazil [abs.]: Geol. Soc. America Spec. Paper 73, p. 196, 1963.

LEONARD, Benjamin Franklin, 3d
1-62. (and HILDEBRAND, F. A., and VLISIDIS, A. C.) Members of the ludwigite-vonsenite series and their distinction from ilvaite, in Petrologic studies--A volume in honor of A. F. Buddington: New York, New York, Geol. Soc. America, p. 523-568, 1962.
1-63. Syenite complex older than the Idaho batholith, Big Creek quadrangle, central Idaho: Art. 204 in U. S. Geol. Survey Prof. Paper 450-E, p. E93-E97, 1963.

LEOPOLD, Estella Bergère
1-61. Regional extinction of late Tertiary relict plant genera in North America [abs.]: Internat. Assoc. Quaternary Research, 6th Cong., Warsaw, 1961, Abs. Papers, p., 118-119, 1961.

LEOPOLD, Luna Bergère
1-62. Rivers: Am. Scientist, v. 50, no. 4, p. 511-537, 1962.
2-62. Water and the arid zone of the United States, in Problems of the arid zone--Proceedings of the Paris Symposium [May 11-18, 1960]: United

LEOPOLD, Luna Bergere
Nations Educ., Sci. and Cultural Organization Arid Zone Research, v. 18, p. 395-399, 1962..
3-62. (and BALDWIN, H. L.) Water: Akron, New York, Saalfield Publishing Co., 48 p., 1962.
1-63. (and NACE, R. L.) Government responsibility for land and water--Guardian or developer?, Chap. in Thorne, Wayne, ed., Land and water use with special reference to the mountain and plains region: Am. Assoc. Adv. Sci. Symposium Volume 73, p. 349-357, 1963.
LESURE, Frank Gardner
1-62. Geology of the Taylor mica mine, Hart County, Georgia: Georgia Mineral Newsletter, v. 15, nos. 1-2, p. 9-14, 1962.
LEVIN, Betsy
1-62. (and FRIEDMAN, Irving) Deuterium in hydrous minerals of the southern California batholith [abs.]: Jour. Geophys.,Research, v. 67, no. 9, p. 3574-3575, 1962.
LEWIS, Richard Quintin, Sr.
1-62. (and THADEN, R. E.) Geology of the Wolf Creek Dam quadrangle, Kentucky: U. S. Geol. Survey [Geol. Quad. Map] GQ-177, 1962.
LICHTLER, William F.
1-63. (and ANDERSON, Warren, and JOYNER, B. F.) Interim report on the water resources of Orange County, Florida: U. S. Geol. Survey open-file report, 57 p., 1963.
LIESCH, Bruce A.
1-63. (and PRICE, C. E., and WALTERS, K. L.) Geology and ground-water resources of northwestern King County, Washington: Washington State Div. Water Resources Water Supply Bull. 20, 241 p., 1963. (Prepared in coop. with U. S. Geological Survey Ground-Water Branch.)
LINDBERG, Marie Louise Lange
1-62. (and WEEKS, A. D., and THOMPSON, M. E., and ELSTON, D. P., and MEYROWITZ, Robert) Hendersonite, a new calcium vanadyl vanadate from Colorado and New Mexico: Am. Mineralogist, v. 47, nos. 11-12, p. 1252-1272, 1962.
LIPMAN, Peter W.
1-63. (and CHRISTIANSEN, R. L.) Relationships between Basin-Range faulting and Timber Mountain caldera, southern Nevada [abs.]: Am. Geophys. Union Trans., v. 44, no. 1, p. 113, 1963.
LITTLER, Janet
1-62. Specific gravity and index of refraction of some australites and Muldoon bediasites, in Astrogeologic studies--Semiannual progress report, Feb. 26, 1961 to Aug. 24, 1961: U. S. Geol. Survey open-file report, p. 48-57, 1962.
2-62. (and FAHEY, J. J., and DIETZ, R. S., and CHAO, E. C.-T.) Coesite from the Lake Bosumiwi Crater, Ashanti, Ghana, in Astrogeologic studies--Semiannual progress report, Feb. 26, 1961 to Aug. 24, 1961: U. S. Geol. Survey open-file report, p. 79-86, 1962.
LIVINGSTONE, Daniel Archibald
1-63. Chemical composition of rivers and lakes, Chap. G in Fleischer, Michael, ed., Data of geochemistry, 6th edition: U. S. Geol. Survey Prof. Paper 440-G, p. G1-G64, 1963.
LOELTZ, Omar Joseph
1-63. Quantitative ground-water investigations in the Lower Colorado River area: U. S.,Geol. Survey open-file report, 7 p., 1963.
LOHMAN, Stanley William
1-62. Geology and artesian water supply of the Grand Junction area, Colorado: U. S. Geol. Survey open-file report, 435 p., 1962.
LONEY, Robert Ahlberg
1-63. (and CONDON, W. H., and DUTRO, J. T., Jr.) Geology of the Freshwater Bay area, Chichagof Island, Alaska: U. S. Geol. Survey Bull. 1108-C, p. C1-C54, 1963.
2-63. Superposed folding in the Pybus-Gambier area, Admiralty Island, Alaska [abs.]: Geol. Soc. America Spec. Paper 73, p. 47, 1963.
LONG, Archie T.
1-63. Ground-water hydrology of Edwards County, Texas: U. S. Geol. Survey Water-Supply Paper 1619-J, p. J1-J29, 1963.
LONGWELL, Chester Ray
1-62. Restudy of the Arrowhead fault, Muddy Mountains, Nevada: Art. 144 in U. S. Geol. Survey Prof. Paper 450-D, p. D82-D85, 1962.
LOPEZ, Miguel A.
1-62. Floods at Bayamón and Cataño, Puerto Rico: U. S. Geol. Survey Hydrol. Inv. Atlas HA-77, 1962 [1963].
2-62. Floods at Bayamón and Cataño, Puerto Rico: U. S. Geol. Survey open-file report, 7 p., 1962.
LOVE, John David
1-62. (and BLACKMON, P. D.) Alunite on Aspen Mountain, southwestern Wyoming, in U. S. Geol. Survey Prof. Paper 450-D, p. D11-D15, 1962.
2-62. (and TAYLOR, D. W.) Faulted Pleistocene strata near Jackson, northwestern Wyoming: Art. 160 in U. S. Geol. Survey Prof. Paper 450-D, p. D136-D139, 1962.
1-63. (and McGREW, P. O., and THOMAS, H. D.) Relationship of latest Cretaceous and Tertiary deposition and deformation to oil and gas in Wyoming, in Backbone of the Americas: Am. Assoc. Petroleum Geologists Mem. 2, p. 196-208, 1963.
LOVE, Samuel Kenneth
1-61. U. S. Geological Survey research studies, in U. S. Public Health Service, 1961 Symposium on Ground-Water Contamination: Robert A. Taft Sanitary Eng. Center Tech. Rept. W61-5, p. 178-181, 1961.
1-63. (and SLACK, K. V.) Controls on solution and precipitation in reservoirs: U. S. Geol. Survey open-file report, 42 p., 1963.
LOVERING, Thomas Seward
1-61. Sulfide ores formed from sulfide-deficient solutions, in Fiziko-khimicheskie problemy formirovaniya gornykh porod i rud, V. 1: Moscow,

LOVERING, Thomas Seward--Continued
Akad. Nauk SSSR, Inst. Geologii Rudnykh Mestorozhdenii, Petrografii, Mineralogii i Geokhimii, p. 107-137, 1961. (Russian text with English summary.)
1-62. (and MALLORY, W. W.) The Eagle Valley Evaporite and its relation to the Minturn and Maroon Formations, northwest Colorado: Art. 132 in U. S. Geol. Survey Prof. Paper 450-D, p. D45-D48, 1962.
1-63. Trace elements in biogeochemistry and geologic studies [abs.]: Geol. Soc. America Spec. Paper 73, p. 198-199, 1963.
2-63. Epigenetic, diplogenetic, syngenetic, and lithogene deposits: Econ. Geology, v. 58, no. 3, p. 315-331, 1963.
LOVERING, Tom Gray
1-62. The origin of jasperoid in limestone: Econ. Geology, v. 57, no. 6, p. 861-889, 1962.
2-62. (and HAMILTON, J. C.) Criteria for the recognition of jasperoid associated with sulfide ore: Art. 63 in U. S. Geol. Survey Prof. Paper 450-C, p. C9-C11, 1962.
3-62. (and PATTEN, L. E.) The effect of $CO_2$ at low temperature and pressure on solutions supersaturated with silica in the presence of limestone and dolomite: Geochim. et Cosmochim. Acta, v. 26, p. 787-796, 1962.
4-62. Use of non-parametric statistical tests in the interpretation of geological data [abs.]: Mining Eng., v. 14, no. 11, p. 65, 1962.
LOVING, Hugh B.
1-63. Airborne control system: Surveying and Mapping, v. 23, no. 1, p. 91-97, 1963.
LOWRY, Marlin E.
1-62. Development of ground water in the vicinity of Tensleep, Wyoming: U. S. Geol. Survey open-file report, 12 p., 1962.
LUSCZYNSKI, Norbert Joseph
1-62. (and SWARZENSKI, W. V.) Fresh and salty ground water in Long Island, N. Y.: Am. Soc. Civil Engineers Proc., v. 88, Jour. Hydraulics Div., no. HY 4, pt. 1, p. 173-194, 1962.
1-63. 'Interface' between fresh and salty groundwater [abs.]: Am. Geophys. Union Trans., v. 44, no. 1, p. 46, 1963.
LYDDAN, Robert Henry
1-62. Civil requirements for topographic maps: Am. Soc. Civil Engineers Proc., v. 88, Jour. Surveying and Mapping Div., no. SU 1, p. 1-6, 1962.
1-63. Geodetic and cartographic aspects, in Science in the Arctic Ocean Basin--A report by the Committee on Polar Research: Natl. Acad. Sci.--Natl. Research Council Pub. 1086, p. 35-36, 1963.
MABEY, Don Russell
1-62. (and ARMSTRONG, F. C.) Gravity and magnetic anomalies in Gem Valley, Caribou County, Idaho: Art. 140 in U. S. Geol. Survey Prof. Paper 450-D, p. D73-D75, 1962.
1-63. (and GRISCOM, Andrew) Aeromagnetic expression of porphyry copper deposits in the southwestern U. S. [abs.]: Mining Eng., v. 15, no. 1, p. 60, 1963.
2-63. (and TOOKER, E. W., and ROBERTS, R. J.) Gravity and magnetic anomalies in the northern Oquirrh Mountains, Utah: Art. 187 in U. S. Geol. Survey Prof. Paper 450-E, p. E28-E31, 1963.
McANDREWS, Harry
1-63. Geologic map of the Riddle Cut quadrangle, Carbon County, Wyoming: U. S. Geol. Survey Mineral Inv. Field Studies Map MF-263, 1963.
McCABE, John Anthony
1-62. Floods in Kentucky, magnitude and frequency: Kentucky Geol. Survey, Ser. 10, Inf. Cir. 9, 196 p., 1962. (Prepared by U. S. Geological Survey and Kentucky Geological Survey in coop. with Kentucky Dept. Commerce.)
McCALL, John Evan
1-62. Planning advanced stream-gaging programs: Eastern Snow Conf., 19th Ann. Mtg., Feb. 8-9, 1962, Proc., p. 133-141, 1962.
2-62. Stream-gaging network in the United States: Am. Soc. Civil Engineers Proc., v. 88, Jour. Hydraulics Div., no. HY 4, pt. 1, p. 231-232, 1962. (Reply to discussion of paper, v. 87, no. HY 2, Mar. 1961, p. 79-95.)
McCARREN, Edward F.
1-63. Chemical quality of surface water in the West Branch Susquehanna River basin, Pennsylvania: U. S. Geol. Survey open-file report, 69 p., 1963.
McCARTHY, J. Howard, Jr.
1-59. Accuracy and precision of field methods of trace analyses used in geochemical exploration by U. S. Geological Survey, in García Rojas, Antonio, Symposium de exploración geoquímica, Tomo 2: México, D. F., Internat. Geol. Cong., 20th, 1956, p. 363-375, 1959.
McCARTNEY, David
1-62. (and BEAMER, N. H.) Continuous recording of water quality in the Delaware estuary: Am. Water Works Assoc. Jour., v. 54, no. 10, p. 1193-1200, 1962.
McCLELLAND, Elver J.
1-62. Aquifer-test compilation for the San Joaquin Valley, California: U. S. Geol. Survey open-file report, 40 p., 1962.
1-63. Aquifer-test compilation for the Mojave Desert region, California: U. S. Geol. Survey open-file report, 26 p., 1963.
2-63. Aquifer-test compilation for northern California: U. S. Geol. Survey open-file report, 20 p., 1963.
3-63. Aquifer-test compilation for the Upper Santa Ana Valley area, San Bernardino County, California: U. S. Geol. Survey open-file report, 28 p., 1963.
4-63. Aquifer-test compilation for the central coastal region, California: U. S. Geol. Survey open-file report, 53 p., 1963.
5-63. (and HILTON, G. S.) Quality of water in the Terra Bella-Lost Hills area, San Joaquin Valley, California: U. S. Geol. Survey open-file report, 48 p., 1963.

McCOY, Henry J.
1-62. Ground-water resources of Collier County, Florida: Florida Geol. Survey Rept. Inv. 31, 82 p., 1962. (Prepared by U. S. Geological Survey in coop. with Collier County, City of Naples, and Florida Geological Survey.)

McDONALD, Charles Casto
1-63. Progress on water resource investigations in the Lower Colorado River area: U. S. Geol. Survey open-file report, 4 p., 1963.
2-63. (and HUGHES, G. H.) Operation of evapotranspiration tanks near Yuma, Arizona: U. S. Geol. Survey open-file report, 14 p., 1963.

McGOVERN, Harold E.
1-63. (and COFFIN, D. L.) Potential ground-water development in the northern part of the Colorado High Plains: U. S. Geol. Survey open-file report, 18 p., 1963.

McGUINNESS, Charles Lee
1-62. Water for the United States--An analysis of the report of the Senate Select Committee on National Water Resources: Nat. Resources Jour., v. 2, no. 2, p. 187-247, 1962.
2-62. Water in South Dakota: South Dakota State Geol. Survey and South Dakota State Water Resources Comm. Water Resources Rept. 2, 33 p., 1962.
3-62. The ground-water situation in the United States, in Course manual, water quality management, sanitary engineering aspects, water supply and pollution control training: Cincinnati, Ohio, Robert A. Taft Sanitary Eng. Center, p. 6-1-6-18, 1962.

MACK, Frederick K.
1-62. Ground-water supplies for industrial and urban development in Anne Arundel County: Maryland Dept. Geology, Mines and Water Resources Bull. 26, p. 1-72, 82-90, 1962. (Prepared in coop. with U. S. Geological Survey, and Planning and Zoning Commission, Anne Arundel County.)
2-62. (and DIGMAN, R. E.) The ground-water resources of Ontario County, New York: New York Water Resources Comm. Bull. GW-48, 99 p., 1962. (Prepared by U. S. Geological Survey in coop. with New York Water Resources Commission.)
1-63. Ground-water studies in Saratoga County, New York--Pt. 2, Geology and ground-water resources of the West Milton area: New York Water Resources Comm. Bull. GW-49, p. 43-75, 1963.

MacKALLOR, Jules A.
1-62. (and MOXHAM, R. M., and TOLOZKO, L. R., and POPENOE, Peter) Geologic map of the Tordilla Hill-Deweesville area, Karnes County, Texas: U. S. Geol. Survey Geophys. Inv. Map GP-199, 1962 [1963].
1-63. Natural gamma aeroradioactivity of the Georgia Nuclear Laboratory area, Georgia: U. S. Geol. Survey Geophys. Inv. Map GP-351, 1963.
2-63. Aeroradioactivity survey and areal geology of the Georgia Nuclear Laboratory area, northern Georgia (ARMS-I): U. S. Atomic Energy Comm. Rept. CEX-58.4.8, 36 p., 1963. (Report prepared for U. S. Atomic Energy Commission, Civil Effects Test Operations series, by U. S. Geological Survey.)

McKAY, Edward Joseph
1-62. Geologic map of the Yucca Flat quadrangle, Nevada Test Site, Nye County, Nevada: U. S. Geol. Survey Rept. TEI-824, open-file report, 1962. (Report prepared for U. S. Atomic Energy Commission.)

McKEE, Edwin Dinwiddie
1-62. (and REYNOLDS, M. A., and BAKER, C. H., Jr.) Experiments on intraformational recumbent folds in crossbedded sand: Art. 165 in U. S. Geol. Survey Prof. Paper 450-D, p. D155-D160, 1962.
2-62. (and REYNOLDS, M. A., and BAKER, C. J., Jr.) Laboratory studies on deformation in unconsolidated sediment: Art. 164 in U. S. Geol. Survey Prof. Paper 450-D, p. D151-D155, 1962.

McKELVEY, Vincent Ellis
1-62. National goal for mineral resources--Efficient development and full use, in Minerals and energy--Problems, practices, and goals, Western Resources Conference, 1962: Colorado School Mines Quart., v. 57, no. 4, pt. 1, p. 143-152, 1962 [1963].
1-63. Successful new techniques in prospecting for phosphate deposits, in U. S. Dept. State, Natural resources--Minerals and mining, mapping and geodetic control: United Nations Conf. Application Sci. and Technology Benefit Less Developed Areas, Geneva, 1963, U. S. Papers, v. 2, p. 163-172, 1963.

McKENNA, Malcolm Carnegie
1-62. (and ROBINSON, Peter, and TAYLOR, D. W.) Notes on Eocene Mammalia and Mollusca from Tabernacle Butte, Wyoming: Am. Mus. Novitates, no. 2102, 33 p., 1962.

McKENZIE, Morris L.
1-62. Report on U.S.G.S. system of analytical aerotriangulation: Photogramm. Eng., v. 28, no. 5, p. 747-749, 1962.

MacKEVETT, Edward Malcolm, Jr.
1-62. (and IMLAY, R. W.) Jurassic stratigraphy in the McCarthy C-5 quadrangle, Alaska: Art. 133 in U. S. Geol. Survey Prof. Paper 450-D, p. D49-D51, 1962.
1-63. (and BLAKE, M. C., Jr.) Jurassic stratigraphy in the McCarthy C-5 quadrangle, Alaska [abs.]: Geol. Soc. America Spec. Paper 73, p.,49, 288, 1963.

MacKICHAN, Kenneth Allen
1-62. Quality of Water Branch, in Geological investigations in Georgia, 1962: Georgia Mineral Newsletter, v. 15, nos. 3-4, p. 45-46, 1962.
2-62. Water and industry in Georgia: Georgia Mineral Newsletter, v. 15, nos. 1-2, p. 20-22, 1962.

McKNIGHT, Edwin Thor
1-62. How about silver?--Where mined and what now with higher price?: Mining World, v. 24, no. 9, p. 18-21, 1962.

McKNIGHT, Edwin Thor--Continued
2-62. (and NEWMAN, W. L., and KLEMIC, Harry, and HEYL, A. V.) Silver in the United States, exclusive of Alaska and Hawaii: U. S. Geol. Survey Mineral Inv. Resource Map MR-34, 1962.

MACLAY, Robert W.
1-62. Geology and ground-water resources of the Elizabethton-Johnson City area, Tennessee: U. S. Geol. Survey Water-Supply Paper 1460-J, p. 389-436, 1962 [1963]. (Prepared in coop. with Tennessee Division of Geology.)
2-62. (and SCHINER, G. R.) Aquifers in buried shore and glaciofluvial deposits along the Gladstone beach of glacial Lake Agassiz near Stephen, Minnesota: Art. 170 in U. S. Geol. Survey Prof. Paper 450-D, p. D170-D172, 1962.

McMASTER, William M.
1-63. Geology of the Elkmont quadrangle, Alabama-Tennessee: U. S. Geol. Survey open-file report, 28 p., 1963.
2-63. Geology of the Salem quadrangle, Alabama-Tennessee: U. S. Geol. Survey open-file report, 41 p., 1963.

MADDOCK, Thomas, Jr.
1-62. Water resources in Arizona [abs.]: Jour. Geophys. Research, v. 67, no. 9, p. 3533, 1962.
1-63. (and LANGBEIN, W. B.) Discussion of "Unsteady flow of ground water into a surface reservoir," by W. L. Haushild and Gordon Kruse (Am. Soc. Civil Engineers Trans. 1962, v. 127, pt. 1, p. 408-415, 1963): Am. Soc. Civil Engineers Trans. 1962, v. 127, pt. 1, p. 972-982, 1963.

MADSEN, Beth Marie
1-62. Petrography of rocks near the device chamber: U. S. Atomic Energy Comm. Rept. PNE-130F, p. 68-79, 1962. (Report prepared for U. S. Atomic Energy Commission by U. S. Geological Survey for Project Gnome.)

MAEVSKY, Anthony
1-63. (and DRAKE, J. A.) Records and logs of selected wells and test holes and chemical analyses of water in southeastern Massachusetts: U. S. Geol. Survey open-file report, 50 p., 1963.

MALDE, Harold Edwin
1-62. (and POWERS, H. A.) Upper Cenozoic stratigraphy of western Snake River Plain, Idaho: Geol. Soc. America Bull., v. 73, no. 10, p. 1197-1219, 1962.

MALLORY, William Wyman
1-62. Analysis of petroleum potential through regional geologic synthesis, in Econ. Comm. Asia and Far East (ECAFE), Sub.-Comm. on Mineral Resources Devel., 2d Symposium on the Development of the Petroleum Resources of Asia and the Far East--U. S. Contr.: Washington, D. C., U. S. Dept. of the Interior, p. 12-43, 1962.
1-63. Analysis of petroleum potential through regional geologic synthesis: Am. Assoc. Petroleum Geologists Bull., v. 47, no. 5, p. 756-776, 1963.
2-63. Pathfinder uplift of Pennsylvanian age in southern Wyoming: Art. 195 in U. S. Geol. Survey Prof. Paper 450-E, p. E57-E60, 1963.

MALMBERG, Glenn Thomas
1-62. Available water supply of the Las Vegas ground-water basin, Nevada: U. S. Geol. Survey open-file report, 236 p., 1962.
2-62. Two figures projecting water levels and pumpage at Las Vegas, Nevada, through 1970: U. S. Geol. Survey open-file report, 2 sheets, 1962.
3-62. (and EAKIN, T. E.) Ground-water appraisal of Sarcobatus Flat and Oasis Valley, Nye and Esmeralda Counties, Nevada: Nevada Dept. Conserv. and Nat. Resources, Ground-Water Resources--Reconn. Ser. Rept. 10, 38 p., 1962. (Prepared by U. S. Geological Survey in coop. with Nevada Dept. of Conservation and Natural Resources.)

MAMAY, Sergius Harry
1-62. Padgettia, a new genus based on fertile neuropteroid foliage from the Permian of Texas: The Palaeobotanist (Lucknow, India), v. 9, nos. 1-2, p. 53-57, 1962.
1-63. Memorial to Roland W. Brown (1893-1961): Geol. Soc. America Bull., v. 74, no. 6, p. P79-P83, 1963.

MAPEL, William Jameson
1-63. (and PILLMORE, C. L.) Stratigraphic sections and correlation of beds in the Inyan Kara Group and Morrison Formation, north end of the Black Hills, Crook County, Wyoming, and Butte County, South Dakota: U. S. Geol. Survey open-ile report, 95 p., 1963.
2-63. (and PILLMORE, C. L.) Geology of the Inyan Kara Mountain quadrangle, Crook and Weston Counties, Wyoming: U. S. Geol. Survey Bull. 1121-M, p. M1-M56, 1963.

MARCHER, Melvin Vernette
1-62. Geology of the Dover area, Stewart County, Tennessee: Tennessee Div. Geology Rept. Inv. 16, 39 p., 1962. (Prepared in coop. with U. S. Geological Survey.)
2-62. Petrography of Mississippian limestones and cherts from the northwestern Highland Rim, Tennessee: Jour. Sed. Petrology, v. 32, no. 4, p. 819-832, 1962.
3-62. Stratigraphy and structure of rocks of Mississippian age in the northwestern Highland Rim, Tennessee: Tenn. Acad. Sci. Jour., v. 37, no. 4, p. 111-116, 1962.
4-62. (and STEARNS, R. G.) Tuscaloosa Formation in Tennessee: Geol. Soc. America Bull., v. 73, no. 11, p. 1365-1386; reprinted as Tennessee Div. Geology Rept. Inv. 17, 1962.
1-63. Crinoidal bioherms in the Fort Payne Chert (Mississippian) along Caney Fork River, Tennessee [abs.]: Geol. Soc. America Spec. Paper 73, p. 12-13, 1963.
2-63. Crinoidal bioherms in the Fort Payne Chert (Mississippian) along the Caney Fork River, Tennessee: Art. 191 in U. S. Geol. Survey Prof. Paper 450-E, p. E43-E47, 1963.

MARINE, Ira Wendell
1-63. (and PRICE, Donald) Records of selected wells and springs, selected drillers' logs of wells, and chemical analyses of ground and surface

MARINE, Ira Wendell--Continued
water, Jordan Valley, Salt Lake County, Utah: U. S. Geol. Survey open-file report, 31 p., 1963.
2-63. Correlation of water-level fluctuations with climatic cycles in the Oklahoma Panhandle: U. S. Geol. Survey Water-Supply Paper 1669-K, p. K1-K10, 1963.
3-63. Ground-water resources of the Bryce Canyon National Park area, Utah, with a section on The drilling of a test well: U. S. Geol. Survey Water-Supply Paper 1475-M, p. 441-486, 1963.
4-63. (and PRICE, Donald) Selected hydrologic data, Jordan Valley, Salt Lake County, Utah: Utah State Engineer Basic-Data Rept. 4, 30 p., 1963. (Prepared by U. S. Geological Survey in coop. with Utah State Engineer.)

MARK, Helen R.
1-63. (compiler) High-alumina kaolinitic clay in the United States, exclusive of Alaska and Hawaii: U. S. Geol. Survey Mineral Inv. Resource Map MR-37, 1963.

MARSH, Owen Thayer
1-62. Geology of Tertiary rocks in Escambia and Santa Rosa Counties, western Florida: Art. 136 in U. S. Geol. Survey Prof. Paper 450-D, p. D59-D61, 1962.
1-63. Geologic and hydrologic reconnaissance in Haywood, Jackson, and Macon Counties, western North Carolina [abs.]: Geol. Soc. America, Southeastern Sec., Ann. Mtg., Roanoke, Virginia, Apr. 1963, Program, p. 28, 1963.
2-63. Peculiar clay tubes in the Citronelle Formation of northern Florida [abs.]: Geol. Soc. America, Southeastern Sec. Ann. Mtg., Roanoke, Virginia, Apr. 1963, Program, p. 28-29, 1963.

MARSHALL, Charles Harding
1-62. Geologic map and sections of the Letronne region of the Moon: U. S. Geol. Survey Misc. Geol. Inv. Map I-385 (LAC-75), 1962. (Prepared in coop. with National Aeronautics and Space Administration and USAF Aeronautical Chart and Information Center.)
1-63. Geologic map and sections of the Letronne region of the Moon, in Astrogeologic studies--Annual progress report, Aug. 25, 1961 to Aug. 24, 1962, Pt. A, Lunar and planetary investigations: U. S. Geol. Survey open-file report, p. 11 and sheet in pocket, 1963.
2-63. Thickness and structure of the Procellarian System in the Lansberg region of the Moon, in Astrogeologic studies--Annual progress report, Aug. 25, 1961 to Aug. 24, 1962, Pt. A, Lunar and planetary investigations: U. S. Geol. Survey open-file report, p. 12-18, 1963.

MASON, Arnold Caverly
1-62. (and HACKMAN, R. J.) Photogeologic study of the Moon, in Kopal, Zdeněk, and Mikhailov, Z. K., eds., The Moon: Internat. Astron. Union, Leningrad, Dec. 1960, Symposium 14, p..301-315, New York, New York, Academic Press, 1962.

MASON, Curtis Calvin
1-63. Ground-water resources of Refugio County, Texas: U. S. Geol. Survey open-file report, 156 p., 1963.
2-63. Availability of ground water from the Goliad Sand in the Alice area, Texas: Texas Water Comm. Bull. 6301, 109 p., 1963. (Prepared by U. S. Geological Survey in coop. with Texas Water Commission and City of Alice.)

MASURSKY, Harold
1-62. Uranium-bearing coal in the eastern part of the Red Desert area, Wyoming: U. S. Geol. Survey Bull. 1099-B, p. B1-B152, 1962.

MATALAS, Nicholas C.
1-63. Autocorrelation of rainfall and streamflow minimums: U. S. Geol. Survey Prof. Paper 434-B, p. B1-B10, 1963.
2-63. Probability distribution of low flows: U. S. Geol. Survey Prof. Paper 434-A, p. A1-A27, 1963.
3-63. Statistics of a runoff-precipitation relation: U. S. Geol. Survey Prof. Paper 434-D, p. D1-D9, 1963.

MAXSON, Robert Orville
1-63. Topographic surveys for the American economy: Surveying and Mapping, v. 23, no. 1, p. 42-46, 1963.

MAXWELL, Bruce William
1-62. (and DEVAUL, R. W.) Availability of ground water in Butler and Ohio Counties, Kentucky--Sheet 1, Geologic map; sheet 2, Ground water; sheet 3, Generalized columnar section: U. S. Geol. Survey Hydrol. Inv. Atlas HA-26, 1962.
2-62. (and DEVAUL, R. W.) Availability of ground water in Hopkins and Webster Counties, Kentucky--Sheet 1, Geologic map; sheet 2, Ground water; sheet 3, Generalized columnar section: U. S. Geol. Survey Hydrol. Inv. Atlas HA-30, 1962.
3-62. (and DEVAUL, R. W.) Availability of ground water in Union and Henderson Counties, Kentucky--Sheet 1, Geologic map; sheet 2, Ground water; sheet 3, Generalized columnar section: U. S. Geol. Survey Hydrol. Inv. Atlas HA-28, 1962.

MAY, Irving
1-63. (and SCHNEPFE, M. M., and NAESER, C. R.) Strontium sorption studies on crandallite: U. S. Geol. Survey Bull. 1144-C, p. C1-C17, 1963.

MEAD, Cynthia Wooster
1-63. (and CHAO, E. C.-T., and LITTLER, Janet) Metallic spheroids from Meteor Crater, Arizona [abs.]: Am. Geophys. Union Trans., v. 44, no. 1, p. 87, 1963.
2-63. (and LITTLER, Janet, and CHAO, E. C.-T.) Metallic spheroids from Meteor Crater, Arizona, in Astrogeologic studies--Annual progress report, Aug. 25, 1961 to Aug. 24, 1962, Pt. C, Cosmochemistry and petrography: U. S. Geol. Survey open-file report, p. 150-162, 1963.

MEADE, Robert Heber
1-63. Relation of the pore volume of silty sediments to overburden load, particle size, and sorting: Art. 210 in U. S. Geol. Survey Prof. Paper 450-E, p. E111-E114, 1963.

MEIER, Mark Frederick
1-62. Proposed definitions for glacier mass budget terms: Jour. Glaciology (Cambridge, England), v. 4, no. 33, p. 252-261, 1962.
2-62. (and POST, A. S.) Recent variations in mass net budgets of glaciers in western North America, in Symposium of Obergurgl, Sept. 1962: Internat. Assoc. Sci. Hydrology (Gentbrugge, Belgium) Pub. 58, p. 63-77, 1962.
1-63. Mechanics of response of glaciers to climatic change--A progress report [abs.]: Geol. Soc. America Spec. Paper 73, p. 205, 1963.

MEISLER, Harold
1-62. Origin of erosional surfaces in the Lebanon Valley, Pennsylvania: Geol. Soc. America Bull., v. 73, no. 9, p. 1071-1082, 1962.
2-62. Geology and hydrology of the carbonate rocks of the Lebanon Valley, Pennsylvania: U. S. Geol. Survey open-file report, 122 p., 1962.
1-63. Theory on vertical distribution of porosity in carbonate rocks--A study in dynamic equilibrium [abs.]: Geol. Soc. America Spec. Paper 73, p. 205-206, 1963; Ground Water, Jour. Natl. Water Well Assoc., v. 1, no. 2, p. 40, 1963.

MEREWETHER, Edward Allen
1-61. (and HALEY, B. R.) Geology of Delaware quadrangle, Arkansas: Arkansas Geol. and Conserv. Comm. Inf. Circ. 20-A, 30 p., 1961 [1962].

MERRIAM, Charles Warren
1-63. Paleozoic rocks of Antelope Valley, Eureka and Nye Counties, Nevada: U. S. Geol. Survey Prof. Paper 423, 67 p., 1963.

MESNIER, Glennon N.
1-62. (and BECKER, Edith, compilers) Exhibits available for field use: U. S. Geol. Survey open-file report, 28 p., 1962.

METZGER, Donald George
1-63. Progress report on geohydrologic investigation in the Parker-Blythe-Cibola area [Arizona]: U. S. Geol. Survey open-file report, 9 p., 1963.
2-63. Basin sediments near Cibola, Arizona [abs.]: Geol. Soc. America Spec. Paper 73, p. 51-52, 1963.

MEUSCHKE, Jack L.
1-62. (and PETTY, A. J., and GILBERT, F. P.) Aeromagnetic map of the Bellow Falls quadrangle and part of the Lovewell Mountain quadrangle, Cheshire and Sullivan Counties, New Hampshire, and Windham and Windsor Counties, Vermont: U. S. Geol. Survey Geophys. Inv. Map GP-302, 1962.
2-62. (and PETTY, A. J., and GILBERT, F. P.) Aeromagnetic map of the Claremont quadrangle, Sullivan County, New Hampshire, and Windsor County, Vermont: U. S. Geol. Survey Geophys. Inv. Map GP-300, 1962.
3-62. (and PETTY, A. J., and GILBERT, F. P.) Aeromagnetic map of the Hanover quadrangle, Grafton and Sullivan Counties, New Hampshire, and Windsor County, Vermont: U. S. Geol. Survey Geophys. Inv. Map GP-298, 1962.
4-62. (and PETTY, A.,J., and GILBERT, F. P.) Aeromagnetic map of the Mascoma quadrangle and part of the Cardigan quadrangle, Grafton, Merrimack, and Sullivan Counties, New Hampshire, and Windsor County, Vermont: U. S. Geol. Survey Geophys. Inv. Map GP-299, 1962.
5-62. (and PETTY, A. J., and GILBERT, F. P.) Aeromagnetic map of the Strafford quadrangle, Orange and Windsor Counties, Vermont: U. S. Geol. Survey Geophys. Inv. Map GP-296, 1962.
6-62. (and PETTY, A. J., and GILBERT, F. P.) Aeromagnetic map of part of the Sunapee quadrangle, Merrimack and Sullivan Counties, New Hampshire: U. S. Geol. Survey Geophys. Inv. Map GP-301, 1962.
7-62. (and PETTY, A. J., and McCASLIN, W. E.) Aeromagnetic map of the Keene quadrangle and parts of the Brattleboro and Monadnock quadrangles, Cheshire County, New Hampshire, and Windham County, Vermont: U. S. Geol. Survey Geophys. Inv. Map GP-303, 1962.
8-62. (and PHILBIN, P. W., and PETRAFESO, F. A.) Aeromagnetic map of the Deadwood area, Black Hills, South Dakota: U. S. Geol. Survey Geophys. Inv. Map GP-304, 1962.
1-63. (and TYSON, N. S., and others) Aeromagnetic map of the northern part of Lake County, Minnesota: U. S. Geol. Survey Geophys. Inv. Map GP-360, 1963.
2-63. (and JOHNSON, R. W., Jr., and KIRBY, J. R.) Aeromagnetic map of the southwestern part of Custer County, South Dakota: U. S. Geol. Survey Geophys. Inv. Map GP-362, 1963. (Prepared in coop. with South Dakota Industrial Development Expansion Agency.)

MEYER, Frederick W.
1-62. Reconnaissance of the geology and ground-water resources of Columbia County, Florida: Florida Geol. Survey Rept. Inv. 30, 74 p., 1962. (Prepared by U. S. Geological Survey in coop. with Board County Commissioners Columbia County and Florida Geological Survey.)

MEYER, Gerald
1-63. Importance of ground-water supplies following a nuclear attack [abs.]: West Virginia Geol. Survey Newsletter, 5th issue, p. [5], 1963.

MEYER, Walter R.
1-63. Use of a neutron moisture probe to determine the storage coefficient of an unconfined aquifer: Art. 235 in U. S. Geol. Survey Prof. Paper 450-E, p. E174-E176, 1963.

MEYROWITZ, Robert
1-62. Synthesis of large crystals of swartzite: Art. 97 in U. S. Geol. Survey Prof. Paper 450-C, p. C99, 1962.
1-63. A semimicroprocedure for the determination of ferrous iron in nonrefractory silicate minerals: Am. Mineralogist, v. 48, nos. 3-4, p. 340-347, 1963.

MILLER, Everett George
1-62. Observations of tidal flow in the Delaware River: U. S. Geol. Survey Water-Supply Paper 1586-C, p. C1-C26, 1962.
MILLER, Glen Allen
1-62. (and EVENSON, R. E.) Geologic reconnaissance and test-well drilling at proposed Air Force Facility near Lompoc, California: U. S. Geol. Survey open-file report, 16 p., 1962.
MILLER, Ralph LeRoy
1-62. The Pine Mountain overthrust at the northeast end of the Powell Valley anticline, Virginia: Art. 139 in U. S. Geol. Survey Prof. Paper 450-D, p. D69-D72, 1962.
MILLER, Robert David
1-63. (and CRANDELL, D. R.) Glaciation of the upper Nisqually River valley, Washington [abs.]: Geol. Soc. America Spec. Paper 73, p. 52, 1963.
MILLER, Thomas P.
1-63. Geology of the Sugar Grove quadrangle, Kentucky: U. S. Geol. Survey Geol. Quad. Map GQ-225, 1963. (Prepared in coop. with Kentucky Geological Survey.)
MILLER, Wallace Tyrrell
1-63. (and WIARD, L. A., and HANLY, T. F.) Surface waters of Wyoming during 1961 and 1962--Results of investigations by the United States Geological Survey in cooperation with The State Engineer: Wyoming State Engineer, 36th Bienn. Rept. 1961-62, supp. B, Surface waters of Wyoming, 44 p., [1963].
MILTON, Daniel Jeremy
1-62. Natural sinters from Tempe Downs and Mt. Remarkable, Australia in Astrogeologic studies--Semiannual progress report, Feb. 26, 1961 to Aug. 24, 1961: U. S. Geol. Survey open-file report, p. 87, 1962.
2-62. (and LITTLER, Janet, and FAHEY, J. J., and SHOEMAKER, E. M.) Petrography of glassy ejecta from the Scooter 0.5-kiloton high-explosive cratering experiment, Nevada, in Astrogeologic studies--Semi-annual progress report, Feb. 26, 1961 to Aug. 24, 1961: U. S. Geol. Survey open-file report, p. 88-92, 1962.
1-63. (and De CARLI, P. S.) Maskelynite--Formation by explosive shock: Science, v. 140, no. 3567, p. 670-671, 1963.
2-63. (and De CARLI, P. S.) Formation of maskelynite by explosive shock, in Astrogeologic studies--Annual progress report, Aug. 25, 1961 to Aug. 24, 1962, Pt. B, Crater investigations: U. S. Geol. Survey open-file report, p. 18-25, 1963.
3-63. Fused rock from a suspected meteorite impact site at Köfels, Austria, in Astrogeologic studies--Annual progress report, Aug. 25, 1961 to Aug. 24, 1962, Pt. B, Crater investigations: U. S. Geol. Survey open-file report, p. 26-37, 1963.
MINARD, James Pierson
1-62. (and OWENS, J. P.) Application of color aerial photography to geologic and engineering soil mapping: Natl. Acad. Sci.--Natl. Research Council Highway Research Board Bull. 316 (Natl. Acad. Sci.--Natl. Research Council Pub. 962), p. 12-22, 1962.
2-62. (and OWENS, J. P.) Pre-Quaternary geology of the New Egypt quadrangle, New Jersey: U. S. Geol. Survey Geol. Quad. Map GQ-161, 1962.
MOENCH, Robert Hadley
1-63. Preliminary geologic map of the Phillips quadrangle, Maine: U. S. Geol. Survey Mineral Inv. Field Studies Map MF-259, 1963.
2-63. Geologic limitations on the age of uranium deposits, Laguna District: New Mexico Bur. Mines and Mineral Resources Mem. 15, p. 157-166, 1963.
MONROE, Watson Hiner
1-63. Geomorphology and sedimentation of north-central Puerto Rico during the Oligocene and Miocene [abs.]: Geol. Soc. America Spec. Paper 73, p. 207, 1963.
MOORE, Ellen James
1-62. Conrad's Cenozoic fossil marine mollusk type specimens at the Academy of Natural Sciences of Philadelphia: Acad. Nat. Sci. Philadelphia Proc., v. 114, no. 2, p. 23-120, 1962.
MOORE,nGeorge William
1-62. The growth of stalactites, in White, W. B., chm., Symposium on cave mineralogy: Natl. Speleol. Soc.,Bull., v. 24, pt. 2, p. 95-104, 1962.
2-62. Role of earth tides in the formation of disc-shaped cave deposits: Internat. Speleol. Cong., 2d, Bari, Italy, 1958, Actes, v. 1, sec. 1, p. 500-506, 1962.
1-63. Abrupt change in cave history when ventilation begins [abs.]: D. C. Speleograph, v. 19, no. 5, supp., p. 2-3, 1963.
MOORE, Gerald K.
1-62. Downdip changes in chemical quality of water in the "500-foot" sand of western Tennessee: Art. 115 in U. S. Geol. Survey Prof. Paper 450-C, p. C133-C134, 1962.
2-62. (and HARRIS, H. B.) Geologic map of Colbert County, Ala.: Alabama Geol.,Survey Geol. Map 20, 1962. (Prepared by U. S. Geological Survey in coop. with Colbert Board Revenue, City of Tuscumbia, and Alabama Geological Survey.)
MOORE, Henry John, 2d
1-62. Current tabulation of data from hypervelocity impact experiments, in Astrogeologic studies--Semiannual progress report, Feb. 26, 1961 to Aug. 24, 1961: U. S. Geol. Survey open-file report, p. 106-112, 1962.
2-62. (and GAULT, D. E., and MacCORMACK, R. W.) Fluid impact craters and hypervelocity--High velocity impact experiments in metals and rocks: U. S. Geol. Survey open-file report, 24 p., 1962; abs., Am. Geophys. Union Trans., v. 43, no. 4, p. 465, 1962.
3-62. (and LUGN, R. V., and GAULT, D. E.) Experimental hypervelocity impact craters in rock: Symposium on Hypervelocity Impact, 5th, Denver, Oct. 30-Nov. 1, 1961, Proc., v. 1, pt. 2, p. 625-643, 1962.
1-63. (and GAULT, D. E.) Relations between dimensions of impact craters and properties of rock targets and projectiles, in Astrogeologic studies--Annual progress report, Aug. 25, 1961 to Aug. 24, 1962, Pt. B, Crater investigations: U. S. Geol. Survey open-file report, p. 38-79, 1963.
2-63. (and GAULT, D. E., and MacCORMACK, R. W.) Fluid impact craters and hypervelocity-high velocity impact experiments in metals and rocks, in Astrogeologic studies--Annual progress report, Aug. 25, 1961 to Aug. 24, 1962, Pt. B, Crater investigations: U. S. Geol. Survey open-file report, p. 80-101, 1963.
MOORE, James Gregory
1-62. (and RICHTER, D. H.) Lava tree molds of the September 1961 eruption, Kilauea Volcano, Hawaii: Geol. Soc. America Bull., v. 73, no. 9, p. 1153-1157, 1962.
2-62. (and RICHTER, D. H.) The 1961 flank eruption of Kilauea volcano, Hawaii [abs.]: Am. Geophys. Union Trans., v. 43, no. 4, p. 446, 1962.
1-63. Geology of the Mount Pinchot quadrangle, southern Sierra Nevada, California: U. S. Geol. Survey Bull. 1130, 152 p., 1963.
2-63. (and GRANTZ, Arthur, and BLAKE, M. C., Jr.) The quartz diorite line in northwestern North America: Art. 203 in U. S. Geol. Survey Prof. Paper 450-E, p. E89-E93, 1963. (Reprinted with additions from Prof. Paper 424-C, 1961.)
MOORE, Samuel Lynn
1-63. Geology of the Tracy quadrangle, Kentucky: U. S. Geol. Survey Geol. Quad. Map GQ-217, 1963. (Prepared in coop. with Kentucky Geological Survey.)
MOREY, George Washington
1-62. The action of water on calcite, magnesite and dolomite: Am. Mineralogist, v. 47, nos. 11-12, p. 1456-1461, 1962.
2-62. (and FOURNIER, R. O., and ROWE, J. J.) The solubility of quartz in water in the temperature interval from 25° to 300°C.: Geochim. et Cosmochim. Acta, v. 26, p. 1029-1043, 1962.
MORRIS, Elliot C.
1-62. (and STEPHENS, H. G.) Photographic investigation of the Earth-Moon libration regions $L_4$ and $L_5$ from Mount Chacaltaya, Bolivia [abs.]: Am. Geophys. Union Trans., v. 43, no. 4, p. 465-466, 1962.
1-63. Albedo measurements in the Lansberg region of the Moon, in Astrogeologic studies--Annual progress report, Aug. 25, 1961 to Aug. 24, 1962, Pt. A, Lunar and planetary investigations: U. S. Geol. Survey open-file report, p. 60-63, 1963.
2-63. (and STEPHENS, H. G.) Photographic investigation of the Earth-Moon libration regions $L_4$ and $L_5$ from Mt. Chacaltaya, Bolivia, in Astrogeologic studies--Annual progress report, Aug. 25, 1961 to Aug. 24, 1962, Pt. A, Lunar and planetary investigations: U. S. Geol. Survey open-file report, p. 64-67, 1963.
MORRIS, Hal Tryon
1-62. (and ANDERSON, J. A.) Eocene topography of the central East Tintic mountains, Utah: Art. 60 in U. S. Geol. Survey Prof. Paper 450-C, p. C1-C4, 1962.
MOTTS, Ward Sundt
1-62. Geology of the West Carlsbad quadrangle, New Mexico: U. S. Geol. Survey Geol. Quad. Map GQ-167, 1962.
2-62. (and CUSHMAN, R. L.) An appraisal of the possibilities of artificial recharge to ground-water supplies in part of the Roswell basin, New Mexico: U. S. Geol. Survey open-file report, 222 p., 1962.
MOULDER, Edward A.
1-63. (and GREGG, D. O., and HORR, C. A.) Public water-supply problems and possibilities for artificial recharge in Colorado: U. S. Geol. Survey open-file report, 67 p., 1963.
MOURANT, Walter Arthur
1-62. Water resources and geology of the Rio Hondo drainage basin, Chaves, Lincoln, and Otero Counties, New Mexico: U. S. Geol. Survey open-file report, 183 p., 1962.
2-62. Site selection and the geology of the shaft at Project Gnome, near Carlsbad, New Mexico [abs.], in New Mexico Geol. Soc., Mogollon Rim region, east-central Arizona, 13th Field Conf., Oct. 1962, Guidebook, p. 174, 1962.
MOWER, Reed W.
1-63. Effect on the shallow artesian aquifer of withdrawing water from the deep artesian aquifer near Sugarville, Utah: U. S. Geol. Survey open-file report, 7 p., 1963.
MOXHAM, Robert Morgan
1-63. Natural radioactivity in Washington County, Maryland: Geophysics, v. 28, no. 2, p. 262-272, 1963.
2-63. Some aerial observations on the terrestrial component of environmental gamma-radiation [abs.]: Internat. Symposium Natural Radiation Environment, Rice Univ., Houston, Texas, Apr. 1963, Program, p. 40, 1963.
MUDGE, Melville Rhodes
1-62. (and SANDO, W. J., and DUTRO, J. T., Jr.) Mississippian rocks of Sun River Canyon area, Sawtooth Range, Montana: Am. Assoc. Petroleum Geologists Bull., v. 46, no. 11, p. 2003-2018, 1962.
2-62. (and YOCHELSON, E. L.) Stratigraphy and paleontology of the uppermost Pennsylvanian and lowermost Permian rocks in Kansas, with sections on Paleontology by R. C. Douglass, Helen Duncan, H. L. Strimple, Mackenzie Gordon, Jr., and D. H. Dunkle: U. S. Geol. Survey Prof. Paper 323, 213 p., 1962 [1963].
MUESSIG, Siegfried Joseph
1-62. Tertiary volcanic and related rocks of the Republic area, Ferry County, Washington: Art. 135 in U. S. Geol. Survey Prof. Paper 450-D, p. D56-D58, 1962.
MUFFLER, L. J. Patrick
1-63. Forcible emplacement of epizonal plutons in the Cortez Mountains, north-central Nevada [abs.]: Geol. Soc. America Spec. Paper 73, p. 208, 1963.

MULLENS, Thomas Ellison
1-63. (and IZETT, G. A.) Geology of the Paradise quadrangle, Utah: U. S. Geol. Survey Geol. Quad. Map GQ-185, 1963.

MULLINEAUX, Donal Ray
1-62. (and CRANDELL, D. R.) Recent lahars from Mount St. Helens, Washington: Geol. Soc. America Bull., v. 73, no. 7, p. 855-869, 1962.

MUNDORFF, James C.
1-62. Sediment discharge during floods in eastern Nebraska: U. S. Geol. Survey Circ. 470, 8 p., 1962.

MUNDORFF, Maurice John
1-62. Ground water in Birch Creek valley, Idaho: U.S. Geol. Survey open-file report, 10 p., 1962.
1-63. (and BROOM, H. C., and KILBURN, Chabot) Reconnaissance of the hydrology of the Little Lost River basin, Idaho: U. S. Geol. Survey Water-Supply Paper 1539-Q, p. Q1-Q51, 1963.

MYERS, Richard E.
1-63. Floods at Des Moines, Iowa: U. S. Geol. Survey Hydrol. Inv. Atlas HA-53, 1963.

MYRICK, Robert M.
1-62. (and COLLINGS, M. R.) Hydrologic aspects of the pinyon and juniper eradication project on the Fort Apache Reservation, Arizona, in New Mexico Geol. Soc., Mogollon Rim region, east-central Arizona, 13th Field Conf., Oct. 1962, Guidebook, p. 140-142, 1962.

NACE, Raymond Lee
1-63. Waters of the earth: Science Teacher, v. 30, no. 3, p. 6-13, 1963.

NELSON, Clemens Arvid
1-63. Preliminary geologic map of the Blanco Mountain quadrangle, Inyo and Mono Counties, California: U. S. Geol. Survey Mineral Inv. Field Studies Map MF-256, 1963.

NELSON, Willis Howard
1-62. Geology of the Holland quadrangle, Kentucky-Tennessee: U. S. Geol. Survey Geol. Quad. Map GQ-174, 1962. (Prepared in coop. with Kentucky Geological Survey.)
1-63. Geology of the Duck Creek Pass quadrangle, Montana: U. S. Geol. Survey Bull. 1121-J, p. J1-J56, 1963.

NEUMAN, Robert Ballin
1-62. The Grand Pitch Formation--New name for the Grand Falls Formation (Cambrian?) in northeastern Maine: Am. Jour. Sci., v. 260, no. 10, p. 794-797, 1962.

NEUSCHEL, Sherman Kennersson
1-63. Correlation of aeroradioactivity and areal geology in District of Columbia and parts of Maryland, Virginia, and West Virginia [abs.]: Geol. Soc. America, Southeastern Sec., Ann. Mtg., Roanoke, Virginia, Apr. 1963, Program, p. 30, 1963.

NEWCOMB, Reuben Clair
1-62. Hydraulic injection of clastic dikes in the Touchet beds, Washington, Oregon, and Idaho [abs.]: Geol. Soc. Oregon Country Geol. News Letter, v. 28, no. 10, p. 70, 1962.
1-63. Résumé of the structure of the White Salmon quadrangle, Oregon-Washington [abs.]: Oregon Acad. Sci., 21st Ann. Mtg., Corvallis, Feb. 1963, Abs. Papers, p. 16, 1963.

NEWCOME, Roy, Jr.
1-62. (and SMITH, Ollie, Jr.) Geology and ground-water resources of the Knox Dolomite in Middle Tennessee: Tennessee Div. Water Resources, Water Resources Ser., no. 4, 43 p., 1962. (Prepared in coop. with U. S. Geological Survey.)
2-62. (and PAGE, L. V.) Water resources of Red River Parish, Louisiana: U. S. Geol. Survey Water-Supply Paper 1614, 133 p., 1962 [1963].

NEWHOUSE, Walter Harry
1-62. (and THAYER, T. P., and BUTLER, A. P., Jr.) Preliminary report on iron ore reserves at Bomi Hills, Liberia: U. S. Geol. Survey open-file report, 22 p., 1962.

NEWMAN, William L.
1-62. Distribution of elements in sedimentary rocks of the Colorado Plateau--A preliminary report: U.S. Geol. Survey Bull. 1107-F, p. 337-445, 1962.

NICHOLS, Donald Raymond
1-63. Origin of the course of the Copper River, Alaska [abs.]: Geol. Soc. America Spec. Paper 73, p. 210, 1963.

NOLAN, Thomas Brennan
1-62. The Eureka mining district, Nevada: U.S. Geol. Survey Prof. Paper 406, 78 p., 1962.
2-62. Role of the geologist in the national economy: Chronique Mines et Recherche Minière (Paris), 30e Année, no. 312, p. 259-268, 1962.
3-62. Water research by the Geological Survey (letter to editor): Science, v. 137, no. 3530, p. 571-572, 1962.
1-63. Current research of the U. S., Geological Survey [abs.]: Am. Assoc. Petroleum Geologists Bull., v. 47, no. 2, p. 365, 1963.

NORDIN, Carl Frederick, Jr.
1-63. Aspects of flow resistance and sediment transport, Rio Grande near Bernalillo, N. Mex.: U.S. Geol. Survey open-file report, 60 p., 1963.

NORRIS, Stanley E.
1-63. Permeability of glacial till: Art. 224 in U. S. Geol. Survey Prof. Paper 450-E, p. E150-E151, 1963.

NORTON, James Jennings
1-62. (and PAGE, L. R., and BROBST, D. A.) Geology of the Hugo pegmatite, Keystone, S. Dak.: U.S. Geol. Survey Prof. Paper 297-B, p. 49-127, 1962.

NORVITCH, Ralph F.
1-62. Geology of the Vermilion end moraine, Nett Lake Indian Reservation, Minnesota: Art. 158 in U. S. Geol. Survey Prof. Paper 450-D, p. D130-D132, 1962.
1-63. Reconnaissance geology and hydrology on the Nett Lake Indian Reservation, Minnesota: U. S. Geol. Survey open-file report, 36 p., 1963.

ODELL, Harold Harley
1-62. Surface Water Branch, in Geological investigations in Georgia, 1962: Georgia Mineral Newsletter, v. 15, nos. 3-4, p. 43-45, 1962.

OGILBEE, William
1-62. (and OSBORNE, F. L., Jr.) Ground-water resources of Haskell and Knox Counties, Texas: Texas Water Comm. Bull. 6209, 174 p., 1962. (Prepared in coop. with U. S. Geological Survey.)
2-62. (and WESSELMAN, J. B.) Geology and ground-water resources of Reeves County--V. 1, Includes records of wells, with a section on Quality of water, by Burdge Irelan: Texas Water Comm. Bull. 6214, v. 1, 193 p., 1962. (Prepared in coop. with U. S. Geological Survey, City of Pecos, and Reeves County.)
3-62. (and WESSELMAN, J. B.) Geology and ground-water resources of Reeves County, Texas--V. 2, Drillers' logs, water levels in wells, and chemical analyses of water, with a section on Quality of water, by Burdge Irelan: Texas Water Comm. Bull. 6214, v. 2, 245 p., 1962. (Prepared in coop. with U. S. Geological Survey, City of Pecos, and Reeves County.)
1-63. (and VORHIS, R. C., and RUSSO, Aurelio) Ground-water resources of the Surman area, Tripolitania, United Kingdom of Libya: U. S. Geol. Survey open-file report, 75 p., 1963.

OLDALE, Robert N.
1-62. Sedimentary rocks of Triassic age in northeastern Massachusetts: Art. 71 in U. S. Geol. Survey Prof. Paper 450-C, p. C31-C32, 1962.
2-62. (and TUTTLE, C. R.) Preliminary report on the seismic investigations in the Orleans, Wellfleet, North Truro, and Provincetown quadrangles, Massachusetts: U. S. Geol. Survey open-file report, 1 sheet, 1962.
3-62. (and TUTTLE, C. R., and CURRIER, L. W.) Preliminary report on the seismic investigations in the Harwich and Dennis quadrangles, Massachusetts: U. S. Geol. Survey open-file report, 1 sheet, 1962.
4-62. Geologic map of the Reading quadrangle, Massachusetts--Surficial geology: U. S. Geol. Survey Geol. Quad. Map GQ-168, 1962 [1963].

OLIVE, Wilds Williamson
1-63. Geology of the Elva quadrangle, Kentucky: U. S. Geol. Survey Geol. Quad. Map GQ-230, 1963. (Prepared in coop. with Kentucky Geological Survey.)

OLIVER, Howard William
1-63. (and MABEY, D. R.) Regional gravity anomalies in central California [abs.]: Am. Assoc. Petroleum Geologists Pacific Sec., 38th Ann. Mtg., Los Angeles, California, Apr. 1963, Program, p. 7, 1963.

OLIVER, William Albert, Jr.
1-62. A new *Kodonophyllum* and associated rugose corals from the Lake Matapedia area, Quebec, [Chap.] C in Silurian corals from Maine and Quebec: U. S. Geol. Survey Prof. Paper 430, p. 21-31, 1962 [1963].
2-62. Redescription of three species of corals from the Lockport Dolomite in New York: U. S. Geol. Survey Prof. Paper 414-G, p. G1-G9, 1962 [1963].
3-62. Silurian rugose corals from the Lake Témiscouata area, Quebec, [Chap.] B in Silurian corals from Maine and Quebec: U. S. Geol. Survey Prof. Paper 430, p. 11-19, 1962 [1963].

OLMSTED, Franklin Howard
1-62. (and PARKER, G. G., and KEIGHTON, W. B., Jr.) Ground-water resources of the Delaware River service area, with special sections by N. M. Perlmutter and R. V. Cushman--App. N., General geology and ground water, in Delaware River Basin, New York, New Jersey, Pennsylvania, and Delaware: U. S. Cong., 87th, 2d sess., House Doc. 522, v. 7, 155 p., 1962. (Prepared for and in coop. with U. S. Army, Corps of Engineers, Philadelphia District.)
1-63. Geology along U. S. Highway 40 between Rocklin and Auburn, in Geol. Soc. Sacramento, U. S. Highway 40, Sacramento to Reno, Dixie Valley and Sand Springs Range, Nevada, Ann. Field Trip, June 1962, Guidebook, p. 54-55, 1963.

OLSON, Jerry Chipman
1-62. (and ADAMS, J. W.) Thorium and rare earths in the United States, exclusive of Alaska and Hawaii: U. S. Geol. Survey Mineral Inv. Resource Map MR-28, 1962.

ORIEL, Steven S.
1-62. Main body of Wasatch Formation near La Barge, Wyoming: Am. Assoc. Petroleum Geologists Bull., v. 46, no. 12, p. 2161-2173, 1962.
2-62. (and GAZIN, C. L., and TRACEY, J. I., Jr.) Eocene age of Almy Formation, Wyoming, in its type area: Am. Assoc. Petroleum Geologists Bull., v. 46, no. 10, p. 1936-1937, 1962.
1-63. Preliminary geologic map of the Fort Hill quadrangle, Lincoln County, Wyoming: U. S. Geol. Survey Oil and Gas Inv. Map OM-212, 1963.

OSTENSO, Ned A.
1-62. (and HOLMES, G. W.) Gravimetric determinations of ice thickness of Jarvis Glacier, Alaska: Art. 94 in U. S. Geol. Survey Prof. Paper 450-C, p. C93-C96, 1962.

O'SULLIVAN, Robert Brett
1-62. Age of Karla Kay Conglomerate Member of Burro Canyon Formation, Colorado and Utah: Am. Assoc. Petroleum Geologists Bull., v. 46, no. 9, p. 1734-1735, 1962.

OTTON, Edmond George
1-62. Geophysical-logging methods as an aid to ground-water development in an area of crystalline rocks [abs.]: Water Well Jour., v. 16, no. 10, p. 61, 1962; Ground Water, Jour. Natl. Water Well Assoc., v. 1, no. 2, p. 38, 1963.

OUTERBRIDGE, William F.
1-63. Geology of the Inez quadrangle, Kentucky: U. S. Geol. Survey Geol. Quad. Map GQ-226, 1963. (Prepared in coop. with Kentucky Geological Survey.)

OVERSTREET, William Courtney

1-62. (and BELL, Henry, 3d) Generalized geologic map of South Carolina [abs.]: South Carolina Div. Geology Geol. Notes, v. 6, no. 4, p. [49], 1962.

2-62. (and BELL, Henry, 3d, and ROSE, H. J., Jr., and STERN, T. W.) Recent lead-alpha age determinations on zircon from the Carolina Piedmont: South Carolina Div. Geology Geol. Notes, v. 6, no. 5, p. 58-62, 1962. (Reprinted from U. S. Geol. Survey Prof. Paper 424-B, 1961.)

3-62. (and GRIFFITTS, W. R.) Preliminary geologic map of the southeast quarter of the Shelby quadrangle, Cleveland County, North Carolina: U. S. Geol. Survey Mineral Inv. Field Studies Map MF-250, 1962.

4-62. (and MEUSCHKE, J. L., and MOXHAM, R. M.) Airborne-radioactivity survey of the northern part of the Shelby quadrangle, Cleveland and Rutherford Counties, North Carolina: U. S. Geol. Survey Geophys. Inv. Map GP-408, 1962.

5-62. (and STERN, T. W., and ANNELL, C. S., and WESTLEY, Harold) Lead-alpha ages of zircon from North and South Carolina: Art. 88 in U. S. Geol. Survey Prof. Paper 450-C, p. C81, 1962.

1-63. Regional heavy-mineral reconnaissance as a guide to ore deposits in deeply weathered areas with semi-humid to humid, temperature to tropic climate, in U. S. Dept. State, Natural resources--Minerals and mining, mapping and geodetic control: United Nations Conf. Application Sci. and Technology Benefit Less Developed Areas, Geneva, 1963, U. S. Papers, v. 2, p. 149-162, 1963.

2-63. (and WHITLOW, J. W., and WHITE, A. M., and GRIFFITTS, W. R.) Geologic map of the southern part of the Casar quadrangle, Cleveland, Lincoln, and Burke Counties, North Carolina, showing areas mined for monazite and mica: U. S. Geol. Survey Mineral Inv. Field Studies Map MF-257, 1963.

PACKARD, Earl Leroy

1-62. (and JONES, D. L.) A new species of Anisoceras from Oregon: Jour. Paleontology, v. 36, no. 5, p. 1047-1050, 1962.

PAGE, Harry G.

1-62. (and WAYMAN, C. H., and ROBERTSON, J. B.) Comparison of three methods for estimating density of Escherichia coli in laboratory preparations: Art. 99 in U. S. Geol. Survey Prof. Paper 450-C, p. C100-C102, 1962.

1-63. (and WAYMAN, C. H., and ROBERTSON, J. B.) Behavior of detergents (ABS), bacteria, and dissolved solids in water-saturated soils: Art. 237 in U. S. Geol. Survey Prof. Paper 450-E, p. E179-E181, 1963.

PAKISER, Louis Charles, Jr.

1-62. (and HEALY, J. H., and ROLLER, J. C.) Crustal structure in the western United States [abs.]: Jour. Geophys. Research, v. 67, no. 9, p. 3585, 1962.

1-63. Structure of the crust and upper mantle in the western United States [abs.]: Am. Geophys. Union Trans., v. 44, no. 1, p. 96-97; Pacific Petroleum Geologist, v. 17, no. 3, p. 1; Rocky Mtn. Assoc. Geologists Newsletter, Apr. 1963, p. 8, 1963.

PALMER, Allison Ralph

1-62. Glyptagnostus and associated trilobites in the United States: U. S. Geol. Survey Prof. Paper 374-F, p. F1-F49, 1962.

PALMQUIST, Wilbur Nathaniel, Jr.

1-62. (and JOHNSON, A. I.) Vadose flow in layered and nonlayered materials: Art. 119 in U. S. Geol. Survey Prof. Paper 450-C, p. C142-C143, 1962.

PANGBORN, Mark White, Jr.

1-63. (compiler) Bibliography of oceanographic publications: U. S. Federal Council Sci. and Technology, Interagency Comm. Oceanography ICO Pamph. 9, 23 p., 1963.

PANKEY, Titus, Jr.

1-62. Possible thermonuclear activities in natural terrestrial minerals [abs.]: Dissert. Abs., v. 23, no. 4, p. 1395-1396, 1962.

PARKER, Garald Gordon

1-61. Ground water in the Central and Southern Florida Flood Control District: Soil and Crop Sci. Soc. Florida Proc. 1960, v. 20, p. 211-231, [1961].

1-62. (and ADAMS, J. W., and HILDEBRAND, F. A.) A rare sodium niobate mineral from Colorado: Art. 61 in U. S. Geol. Survey Prof. Paper 450-C, p. C4-C6, 1962.

1-63. (and HILDEBRAND, F. A.) Preliminary report on alkalic intrusive rocks in the northern Wet Mountains, Colorado: Art. 181 in U. S. Geol. Survey Prof. Paper 450-E, p. E8-E10, 1963.

2-63. (compiler) Niobium and tantalum in the United States, exclusive of Alaska and Hawaii: U. S. Geol. Survey Mineral Inv. Resource Map MR-36, 1963.

PATTEN, Eugene P., Jr.

1-62. (and BENNETT, G. D.) Methods of flow measurement in well bores: U. S. Geol. Survey Water-Supply Paper 1544-C, p. C1-C28, 1962.

1-63. (and BENNETT, G. D.) Application of electrical and radioactive well logging to ground-water hydrology: U. S. Geol. Survey Water-Supply Paper 1544-D, p. D1-D60, 1963.

PATTEN, Lorraine E.

1-62. (and WARD, F. N.) Geochemical field method for beryllium prospecting: Art. 101 in U. S. Geol. Survey Prof. Paper 450-C, p. C103-C104, 1962.

PATTERSON, Sam Hunting

1-62. Investigation of ferruginous bauxite deposits on Kauai and a reconnaissance of deposits on Maui: U. S. Geol. Survey open-file report, 336 p., 1962.

2-62. (and HOSTERMAN, J. W.) Geology and refractory clay deposits of the Haldeman and Wrigley quadrangles, Kentucky, with a section on Coal resources, by J. W. Huddle: U. S. Geol. Survey Bull. 1122-F, p. F1-F113, 1962 [1963].

PAULSON, Quentin Frank

1-62. Ground water--A vital North Dakota resource: North Dakota Geol. Survey Misc. Ser., no. 16 (North Dakota State Water Conserv. Comm. Inf. Ser. Bull. 1), 26 p., 1962. (Prepared by U. S. Geological Survey in coop. with North Dakota State Water Conservation Commission and North Dakota Geological Survey.)

2-62. Report on test drilling and pumping test in wildlife research project area, James River valley, Stutsman County, North Dakota: U. S. Geol. Survey open-file report, 21 p., 1962.

3-62. (and POWELL, J. E.) Geology and ground water resources of Tioga and Hofflund Flats areas, Williams and Mountrail Counties, North Dakota: North Dakota State Water Conserv. Comm. Ground Water Study 43, 65 p., 1962. (Prepared by U. S. Geological Survey in coop. with North Dakota State Water Conservation Commission and North Dakota Geological Survey.)

4-62. (and MILLER, J. D., Jr., and DRENNEN, C. W.) Ground-water resources and geology of Tuscaloosa County, Alabama: Alabama Geol. Survey County Rept. 6, 97 p., 1962. (Prepared by U. S. Geological Survey in coop. with Tuscaloosa County Board of Revenue and Geological Survey of Alabama.)

PAVLIDES, Louis

1-62. Geology and manganese deposits of the Maple and Hovey Mountains area, Aroostook County, Maine, with a section on Lithology and mineralogy of the deposits, by Louis Pavlides and Charles Milton: U. S. Geol. Survey Prof. Paper 362, 116 p., 1962 [1963].

PEARSON, Robert Carl

1-62. (and TWETO, Ogden, and STERN, T. W., and THOMAS, H. H.) Age of Laramide porphyries near Leadville, Colorado: Art. 87 in U. S. Geol. Survey Prof. Paper 450-C, p. C78-C80, 1962.

PECK, Dallas Lynn

1-62. Preliminary geologic map of the Strawberry mine area, Madera County, California: U. S. Geol. Survey open-file report, 2 sheets, 1962.

PECKHAM, Alan Embree

1-61. (and LIEBERMAN, J. A.) Research in ground water hydrology and its relation to nuclear energy wastes, in U. S. Public Health Service, 1961 Symposium on Ground-Water Contamination: Robert A. Taft Sanitary Eng. Center Tech. Rept. W61-5, p. 198-202, 1961.

PECORA, William Thomas

1-62. Carbonatite problem in the Bearpaw Mountains, Montana, in Petrologic studies--A volume in honor of A. F. Buddington: New York, New York, Geol. Soc. America, p. 83-104, 1962.

2-62. Coesite craters and space geology, in White, J. F., ed., Study of the Earth--Readings in geological science: Englewood Cliffs, New Jersey, Prentice-Hall, Inc., p. 164-171, 1962.

PEIRCE, Howard Wesley

1-62. (and COOLEY, M. E., and JOHNSON, P. W., and BREED, W. J.) Road log from Globe to Flagstaff, Arizona, in New Mexico Geol. Soc., Mogollon Rim region, east-central Arizona, 13th Field Conf., Oct. 1962, Guidebook, p. 31-49, 1962.

PEIRCE, Laurence B.

1-62. Surface water in Tuscaloosa County, Alabama, with a section on Chemical quality of surface water, by R. G. Grantham: Alabama Geol. Survey County Rept. 9, 89 p., 1962. (Prepared by U. S. Geological Survey in coop. with Tuscaloosa County Board of Revenue and Geological Survey of Alabama.)

PEPPER, James Franklin

1-62. Prospective contributions of the International Indian Ocean Expedition to Indian Ocean continental shelf geology, in Econ. Comm. Asia and Far East (ECAFE), Sub.-Comm. on Mineral Resources Devel., 2d Symposium on the Development of the Petroleum Resources of Asia and the Far East--U. S. Contr.: Washington, D. C., U. S. Dept. Interior, p. 1-11, 1962.

PÉREZ LARIOS, José

1-63. (and GUERRA PEÑA, Felipe, and HERNANDEZ SANCHEZ MEJORADA, Santiago, and KENT, B. H., and GARCÍA ROJAS, Antonio) The use of air photographs in the development of the natural resources of Mexico, in U. S. Dept. State, Natural resources--Minerals and mining, mapping and geodetic control: United Nations Conf. Application Sci. and Technology Benefit Less Developed Areas, Geneva, 1963, U. S. Papers, v. 2, p. 183-193, 1963.

PERLMUTTER, Nathaniel Matthew

1-62. Ground-water geology and hydrology of the Maynard area, Massachusetts, with a section on An aquifer test in deposits of glacial outwash, by N. J. Lusczynski: U. S. Geol. Survey Water-Supply Paper 1539-E, p. E1-E69, 1962 [1963].

1-63. (and SOREN, Julian) Effects of major water-table changes in Kings and Queens Counties, New York City: Art. 219 in U. S. Geol. Survey Prof. Paper 450-E, p. E136-E139, 1963.

2-63. (and GERAGHTY, J. J.) Geology and ground-water conditions in southern Nassau and southeastern Queens Counties, Long Island, N. Y.: U. S. Geol. Survey Water-Supply Paper 1613-A, p. A1-A205, 1963.

PESELNICK, Louis

1-62. Elastic constants of Solenhofen limestone and their dependence upon density and saturation: Jour. Geophys. Research, v. 67, no. 11, p. 4441-4448, 1962.

2-62. (and ROBIE, R., A.) Elastic constants of calcite: Jour. Appl. Physics, v. 33, no. 9, p. 2889-2892, 1962.

PESSL, Fred

1-63. Emerged marine features in the Mesters Vig area, East Greenland: Coastal Research Notes, no. 5, p. 8-9, 1963.

PETERSEN, Richard Gray
1-62. Brockton-Pembroke area--Records of selected wells, test holes, ponds, and streams in the Brockton-Pembroke area, Massachusetts: U. S. Geol. Survey Massachusetts Basic-Data Rept. 5, Ground-Water Ser., 46 p., 1962. (Prepared in coop. with Massachusetts Dept. Public Works.)
2-62. (and MAEVSKY, Anthony) Western Massachusetts area--Records and logs of selected wells and test holes, records of selected springs, and chemical analyses of water in western Massachusetts: U. S. Geol. Survey Massachusetts Basic-Data Rept. 6, Ground-Water Ser., 31 p., 1962. (Prepared in coop. with Massachusetts Dept. Public Works.)

PETERSON, Donald William
1-62. Preliminary geologic map of the western part of the Superior quadrangle, Pinal County, Arizona: U. S. Geol. Survey Mineral Inv. Field Studies Map MF-253, 1962.

PETERSON, Harold V.
1-61. Reconnaissance methods of locating stock wells in arid regions of the United States, in Groundwater in arid zones, Symposium of Athens, Sept. 1961, V. 2: Internat. Assoc. Sci. Hydrology (Gentbrugge, Belgium) Pub. 57, p. 628-640, 1961.
1-62. Hydrology of small watersheds in western States: U. S. Geol. Survey Water-Supply Paper 1475-I, p. 217-356, 1962.
2-62. Discussion of "Transmission losses in ephemeral stream beds," by R. V. Keppel and K. G. Renard (Am. Soc. Civil Engineers Proc., v. 88, Jour. Hydraulics Div., no. HY 3, pt. 1, p. 59-68, 1962): Am. Soc. Civil Engineers Proc., v. 88, Jour. Hydraulics Div., no. HY 5, pt. 1, p. 339-343, 1962.
3-62. (and BRANSON, F. A.) Effects of land treatments on erosion and vegetation on range lands in parts of Arizona and New Mexico: Jour. Range Management, v. 12, no. 4, p. 220-226, 1962.

PETERSON, Nels Paul
1-62. Geology and ore deposits of the Globe-Miami district, Arizona: U. S. Geol. Survey Prof. Paper 342, 151 p., 1962.
2-62. Geology and ore deposits of the Globe quadrangle, in New Mexico Geol. Soc., Mogollon Rim region, east-central Arizona, 13th Field Conf., Oct. 1962, Guidebook, p. 158-161, 1962.

PETRI, Lester R.
1-61. The movement of saline ground water in the vicinity of Derby, Colorado, in U. S. Public Health Service, 1961 Symposium on Ground-Water Contamination: Robert A. Taft Sanitary Eng. Center Tech. Rept. W61-5, p. 119-121, 1961.

PETTIJOHN, Francis John
1-63. Chemical composition of sandstones--excluding carbonate and volcanic sands, Chap. S in Fleischer, Michael, ed., Data of geochemistry, 6th edition: U. S. Geol. Survey Prof. Paper 440-S, p. S1-S21, 1963.

PÉWÉ, Troy Lewis
1-61. (and BURBANK, Lawrence) Multiple glaciation in the Yukon-Tanana upland--A photogeologic interpretation [abs.]: Alaska Oil and Gas Yearbook 1960, p. 85-86, 1961.
1-63. (and PAIGE, R. A.) Frost heaving of piles with an example from Fairbanks, Alaska: U. S. Geol. Survey Bull. 1111-I, p. 333-407, 1963.

PHAIR, George
1-62. (and FISHER, F. G.) Laramide comagmatic series in the Colorado Front Range--The feldspars, in Petrologic studies--A volume in honor of A. F. Buddington: New York, New York, Geol. Soc. America, p. 479-521, 1962.
1-63. (and GOTTFRIED, David) The Colorado Front Range, Colorado, U.S.A. as a uranium and thorium province [abs.]: Internat. Symposium Natural Radiation Environment, Rice Univ., Houston, Texas, Apr. 1963, Program, p. 8-9, 1963.

PHILBIN, Philip Wilfred
1-63. (and MEUSCHKE, J. L., and McCASLIN, W. E.) Aeromagnetic map of the Roberts Mountains area, central Nevada: U. S. Geol. Survey open-file report, 2 sheets, 1963.

PIERCE, William Gamewell
1-62. (and RICH, E. I.) Summary of rock salt deposits in the United States as possible storage sites for radioactive waste materials: U. S. Geol. Survey Bull. 1148, 91 p., 1962.
1-63. Cathedral Cliffs Formation, the early acid breccia unit of northwestern Wyoming: Geol. Soc. America Bull., v. 74, no. 1, p. 9-21, 1963.

PILLMORE, Charles Lee
1-63. (and MAPEL, W. J.) Geology of the Nefsy Divide quadrangle, Crook County, Wyoming: U. S. Geol. Survey Bull. 1121-E, p. E1-E52, 1963.

PISTRANG, Marvin A.
1-62. (and KUNKEL, Fred) A brief geologic and hydrologic reconnaissance of the Furnace Creek Wash area, Death Valley National Monument, California: U. S. Geol. Survey open-file report, 77 p., 1962.

PITKIN, James Alfred
1-63. Aeroradioactivity surveys and geologic mapping [abs.]: Internat. Symposium Natural Radiation Environment, Rice Univ., Houston, Texas, Apr. 1963, Program, p. 39, 1963.

PLAFKER, George
1-62. Geologic investigations of proposed powersites at Sheep Creek, Carlson Creek, and Turner Lake, Alaska: U. S. Geol. Survey Bull. 1031-F, p. 127-148, 1962.

PLEBUCH, Raymond O.
1-61. Fresh-water aquifers of Crittenden County, Arkansas: Arkansas Geol. and Conserv. Comm. Water Resources Circ. 8, 65 p., 1961 [1962]. (Prepared by U. S. Geological Survey in coop. with Arkansas Geological and Conservation Commission.)
1-62. Changes in ground-water levels in deposits of Quaternary age in northeastern Arkansas: U. S. Geol. Survey open-file report, 9 p. 1962.

PLEBUCH, Raymond O.--Continued
2-62. Ground-water temperatures in the Coastal Plain of Arkansas: U. S. Geol. Survey open-file report, 5 p., 1962.

PLOUFF, Donald F.
1-62. Bouguer gravity map of the Twin Buttes area, Pima and Santa Cruz Counties, Arizona: U. S. Geol. Survey open-file report, 1962.

POLAND, Joseph Fairfield
1-62. (and GREEN, J. H.) Artesian wells and land subsidence: Johnson Drillers' Jour., v. 34, no. 4, p. 3-5, 1962. (Summary of U. S. Geological Survey Water-Supply Paper 1619-C, 1962.)
1-63. Relation of core expansion to the laboratory determination of porosity of alluvial sediments [abs.]: Am. Geophys. Union Trans., v. 44, no. 1, p. 46, 1963.

POLLOCK, Samuel J.
1-60. Ground-water map of the North Scituate quadrangle, Rhode Island, showing water-bearing formations and related ground-water data: Rhode Island and Providence Plantations Water Res. Coord. Board Ground-Water Map GWM 12, 1960. (Prep. in coop. with U.S.Geol. Survey.)

POOLE, Forrest Graham
1-62. Wind directions in late Paleozoic to middle Mesozoic time on the Colorado Plateau: Art. 163 in U. S. Geol. Survey Prof. Paper 450-D, p. D147-D151, 1962.
2-62. (and McKEOWN, F. A.) Oak Spring Group of the Nevada Test Site and vicinity, Nevada: Art. 80 in U. S. Geol. Survey Prof. Paper 450-C, p. C60-C62, 1962.

POOLE, Joe L.
1-62. Saline ground water--A little used and unmapped resource [abs.]: Water Well Jour., v. 16, no. 10, p. 44, 46, 1962; Ground Water, Jour. Natl. Water Well Assoc., v. 1, no. 2, p. 36, 1963.

POPENOE, Peter
1-62. (and ANDREASEN, G. E., and KIRBY, J. R.) Aeromagnetic map of the Bethel quadrangle, Fairfield County, Connecticut: U. S. Geol. Survey Geophys. Inv. Map GP-368, 1962 [1963].
2-62. (and ANDREASEN, G. E., and KIRBY, J. R.) Aeromagnetic map of the Botsford quadrangle, Fairfield County, Connecticut: U. S. Geol. Survey Geophys. Inv. Map GP-369, 1962 [1963].
3-62. (and ANDREASEN, G. E., and KIRBY, J. R.) Aeromagnetic map of the Peach Lake quadrangle, Fairfield County, Connecticut, and Putnam and Westchester Counties, New York: U. S. Geol. Survey Geophys. Inv. Map GP-367, 1962 [1963].
4-62. (and BROMERY, R. W., and KIRBY, J. R.) Aeromagnetic map of the Brewster quadrangle, Fairfield County, Connecticut, and Putnam County, New York: U. S. Geol. Survey Geophys. Inv. Map GP-364, 1962 [1963].
5-62. (and BROMERY, R. W., and KIRBY, J. R.) Aeromagnetic map of the Danbury quadrangle, Fairfield and Litchfield Counties, Connecticut: U. S. Geol. Survey Geophys. Inv. Map GP-365, 1962 [1963].
6-62. (and BROMERY, R. W., and KIRBY, J. R.) Aeromagnetic map of the Newtown quadrangle, Fairfield, Litchfield, and New Haven Counties, Connecticut: U. S. Geol. Survey Geophys. Inv. Map GP-366, 1962

POST, Edwin Vanhorn
1-63. (and JOHNSTON, J. E.) Geology of the Lee City quadrangle, Kentucky: U. S. Geol. Survey Geol. Quad. Map GQ-198, 1963. (Prepared in coop. with Kentucky Geological Survey.)

POWELL, John Edward
1-62. (and JONES, S. L.) Ground-water resources in the Lakota area, Nelson County, North Dakota: U. S. Geol. Survey open-file report, 91 p., 1962.

POWELL, William J.
1-61. (and LaMOREAUX, P. E.) Relation of the geologic structure of the Huntsville area, Alabama, to the occurrence of ground water in a limestone terrane [abs.]: Alabama Acad. Sci. Jour., v. 32, no. 4, p. 225-226, 1961.

POWERS, Howard Adorno
1-63. Important developments in volcanology [abs.]: Geol. Soc. America Spec. Paper 73, p. 218, 1963.

PRAKASH, Uttam
1-62. (and BARGHOORN, E. S., and SCOTT, R. A.) Fossil wood of Robinia and Gleditsia from the Tertiary of Montana: Am. Jour. Botany, v. 49, no. 7, p. 692-696, 1962.

PRESCOTT, Glenn Carleton, Jr.
1-62. (and DRAKE, J. A.) Southwestern area--Records of selected wells, test holes, and springs in southwestern Maine: U. S. Geol. Survey Maine Basic-Data Rept. 1, Ground-Water Ser., 35 p., 1962. (Prepared in coop. with Maine Public Utilities Commission.)
2-62. (and DRAKE, J. A.), Records of selected wells, test holes, and springs in southwestern Maine: U. S. Geol. Survey open-file report, 34 p., 1962.
3-62. Ground-water resources of Maine: Maine Water Resources Symposium, Univ. Maine, May 1962, Proc., p. 29-34, 1962. (Prepared by U. S. Geological Survey in coop. with Maine Public Utilities Commission.)

PRICE, William Evans, Jr.
1-62. (and KILBURN, Chabot, and MULL, D. S.) Availability of ground water in Boyd, Carter, Elliott, Greenup, Johnson, Lawrence, Lee, Menifee, Morgan, and Wolfe Counties, Kentucky--Sheet 1, Geologic map; sheet 2, Ground water; sheet 3, Generalized columnar section: U. S. Geol. Survey Hydrol. Inv. Atlas HA-37, 1962.
2-62. (and MULL, D. S., and KILBURN, Chabot) Reconnaissance of ground-water resources in the Eastern Coal Field region, Kentucky: U. S. Geol. Survey Water-Supply Paper 1067, 56 p., 1962.

PRICHARD, George Edwards
1-63. (and JOHNSTON, J. E.), Geology of the Jackson quadrangle, Kentucky: U. S. Geol. Survey Geol. Quad. Map GQ-205, 1963.

PRIDE, Roland Wynn
1-62. Floods at Tampa, Florida: U. S. Geol. Survey Hydrol. Inv. Atlas HA-66, 2 sheets, 1962 [1963].
2-62. Floods at Tampa, Florida: U. S. Geol. Survey open-file report, 7 p., 1962.
3-62. (and CROOKS, J. W.) The drought of 1954-56, its effect on Florida's surface-water resources: Florida Geol. Survey Rept. Inv. 26, 65 p., 1962. (Prepared by U. S. Geological Survey in coop. with Florida Geological Survey.)
PRILL, Robert C.
1-63. (and JOHNSON, A. I.) Centrifuge technique for determining time-drainage relations for a natural sand: Art. 236 in U. S. Geol. Survey Prof. Paper 450-E, p. E177-E178, 1963.
PRINZ, William Charles
1-63. Geologic maps and sections of part of the Philipsburg district, Granite County, Montana: U. S. Geol. Survey open-file report, 7 sheets, 1963.
PRIVRASKY, Norman Calvin
1-63. Geology of the Big Piney area, Sublette County, Wyoming: U. S. Geol. Survey Oil and Gas Inv. Map OM-205, 2 sheets, 1963.
PRZEWLOCKI, Kazimierz
1-62. (and MAGDA, Wilhelm, and THOMAS, H. H., and FAUL, Henry) Age of some granitic rocks in Poland: Geochim. et Cosmochim. Acta, v. 26, p. 1069-1075, 1962.
PUFFETT, Willard Penry
1-62. Geology of the Sawyer quadrangle, Kentucky: U. S. Geol. Survey Geol. Quad Map GQ-179, 1962.
1-63. Geology of the Vox quadrangle, Kentucky: U. S. Geol. Survey Geol. Quad. Map GQ-224, 1963.
2-63. Geology of the Corbin quadrangle, Kentucky: U. S. Geol. Survey Geol. Quad. Map GQ-231, 1963. (Prepared in coop. with Kentucky Geological Survey.)
PUSEY, Richard D.
1-60. Geology and ground water in the Goldsboro area, North Carolina: North Carolina Dept. Water Resources Ground-Water Bull. 2, 77 p., 1960. (Prepared by U. S. Geological Survey in coop. with North Carolina Dept. Water Resources.
RADBRUCH, Dorothy Hill
1-63. (and WEILER, L. M.) Preliminary report on landslides in a part of the Orinda Formation, Contra Costa County, California: U. S. Geol. Survey open-file report, 35 p., 1963.
RAINWATER, Frank Hays
1-62. Stream composition of the conterminous United States: U. S. Geol. Survey Hydrol. Inv. Atlas HA-61, 3 sheets, 1962.
RANDALL, Allan D.
1-60. (and BIERSCHENK, W. H., and HAHN, G. W.) Ground-water map of the Voluntown quadrangle, Connecticut-Rhode Island, showing water-bearing formations and related ground-water data: Rhode Island and Providence Plantations Water Resources Coordinating Board Ground-Water Map GWM 13, 1960. (Prepared in coop. with U. S. Geological Survey and Connecticut Water Resources Commission.)
1-63. Records and logs of selected wells and test borings, records of springs, and chemical analyses of water in the Farmington-granby area, Connecticut: U. S. Geol. Survey open-file report, 7 p., 1963.
RANDICH, Philip G.
1-62. (and BRADLEY, Edward) Ground-water resources in the vicinity of Leeds, Benson County, North Dakota: North Dakota State Water Conserv. Comm., North Dakota Ground-Water Study 44, 27 p., 1962. (Prepared by U. S. Geological Survey in coop. with North Dakota State Water Conservation Commission and North Dakota Geological Survey.)
2-62. (and PETRI, L. R., and ADOLPHSON, D. G.) Geology and ground water resources of Kidder County, North Dakota--Pt. 2, Ground water basic data: North Dakota Geol. Survey Bull. 36, pt. 2 (North Dakota State Water Conserv. Comm. County Ground Water Study 1, pt. 2), 134 p., 1962. (Prepared by U. S. Geological Survey in coop. with North Dakota Geological Survey and North Dakota State Water Conservation Commission.)
1-63. Geology and ground water resources of the Linton-Strasburg area, Emmons County, North Dakota: North Dakota State Water Conserv. Comm., North Dakota Ground-Water Study 50, 52 p., 1963. (Prepared by U. S. Geological Survey in coop. with North Dakota State Water Conservation Commission and North Dakota Geological Survey.)
RANSON, Helen F.
1-62. (and LEOPOLD, E. B.) The Standard rain gage as an efficient sampler of air-borne pollen and spores [abs.]: Pollen et Spores (Paris), v. 4, no. 2, p. 373, 1962.
RANTZ, Saul Edward
1-62. Diurnal fluctuation of free-water content and density in a melting snow-pack: Western Snow Conf., 30th Ann. Mtg., Cheyenne, Wyoming, Apr. 16-18, 1962, Proc., p. 30-31, 1962.
2-62. Flow of springs and small streams in the Tecolote Tunnel area of Santa Barbara County, California: U. S. Geol. Survey Water-Supply Paper 1619-R, p. R1-R26, 1962.
1-63. Snowmelt hydrology of a Sierra Nevada stream: U. S. Geol. Survey open-file report, 71 p., 1963.
RAPP, John Richard
1-62. Roll in a sandstone lentil of the Green River Formation: Art. 91 in U. S. Geol. Survey Prof. Paper 450-C, p. C85-C87, 1962.
RAU, Jon Llewellyn
1-62. (and BAKKEN, W. E., and CHMELIK, James, and WILLIAMS, B. J.) Geology and ground water resources of Kidder County, North Dakota--Pt. 1, Geology: North Dakota Geol. Survey Bull. 36, pt. 1 (North Dakota State Water Conservation Commission County Ground Water Study 1, pt. 1), 70 p., 1962.
RAUP, David Malcolm
1-63. (and LAWRENCE, David R.) Paleoecology of Pleistocene mollusks from Marthas Vineyard, Massachusetts: Jour. Paleontology, v. 37, no. 2, p. 472-485, 1963.
RAUP, Omer Beaver
1-63. Clay mineralogy of the Pennsylvanian red beds and associated rocks flanking the ancestral Front Range of central Colorado [abs.]: Dissert. Abs., v. 23, no. 10, p. 3865-3866, 1963.
RAY, Louis Lamy
1-63. Silt-clay rates of weathering profiles of Peorian loess along the Ohio Valley: Jour. Geology, v. 71, no. 1, p., 38-47, 1963.
READ, Charles B.
1-62. The classification of copper deposits in sandstone and associated rocks in the southwestern States [abs.], in New Mexico Geol. Soc., Mogollon Rim region, east-central Arizona, 13th Field Conf., Oct. 1962, Guidebook, p. 175, 1962.
REDFIELD, Alfred C.
1-62. (and RUBIN, Meyer) The age of salt marsh peat and its relation to recent changes in sea level at Barnstable, Massachusetts: Natl. Acad. Sci. Proc., v. 48, no. 10, p. 1728-1735, 1962.
REEDER, Harold Oliver
1-62. (and others) Ground-water levels in New Mexico, 1959: New Mexico State Engineer Tech. Rept. 24, 125 p., 1962. (Prepared in coop. with U. S. Geological Survey.)
REESIDE, John Bernard, Jr.
1-62. Cretaceous ammonites of New Jersey, in The Cretaceous fossils of New Jersey: New Jersey Bur. Geology and Topography Bull. 61, pt. 2, p. 113-137, 1962.
REICHEN, Laura Esther
1-62. (and FAHEY, J. J.) An improved method for the determination of FeO in rocks and minerals including garnet: U. S. Geol. Survey Bull. 1144-B, p. B1-B5, 1962.
REMSON, Irwin
1-62. (and RANDOLPH, J. R.) Review of some elements of soil-moisture theory: U. S. Geol. Survey Prof. Paper 411-D, p. D1-D38, 1962.
RHODEHAMEL, Edward Charles
1-62. (and LANG, S. M.) Winter ground-water temperatures along the Mullica River, Wharton Tract, New Jersey: Art. 168 in U. S. Geol. Survey Prof. Paper 450-D, p. D165-D168, 1962.
1-63. (and CARLSTON, C. W.) Geologic history of the Teays Valley in West Virginia: Geol. Soc. America Bull., v. 74, no. 3, p. 251-273, 1963.
RICE, Charles L.
1-63. Geology of the Thomas quadrangle, Kentucky: U. S. Geol. Survey Geol. Quad. Map GQ-225, 1963. (Prepared in coop. with Kentucky Geological Survey.)
RICH, Ernest I.
1-62. Reconnaissance geology of Hiland-Clarkson Hill area, Natrona County, Wyoming: U. S. Geol. Survey Bull. 1107-G, p. 447-540, 1962.
RICHARDS, Horace Gardiner
1-62. (and OLMSTED, F. H., and RUHLE, J. L.) Generalized structure contour maps of the New Jersey Coastal Plain: New Jersey Geol. Survey Geol. Rept. Ser., no. 4, 38 p., 1962. (Prepared by U. S. Geological Survey in coop. with New Jersey Div. Water Policy and Supply.)
RICHARDSON, Claire Alice
1-62. Chemical character of the water, in Ground-water supplies for industrial and urban development in Anne Arundel County: Maryland Dept. Geology, Mines and Water Resources Bull. 26, p. 75-81, 1962. (Prepared in coop. with U. S. Geological Survey and Planning and Zoning Commission, Anne Arundel County.)
RICHARDSON, Donald
1-63. Drainage-area data for western Washington: U. S. Geol. Survey open-file report, 244 p., 1963.
RICHARDSON, Everett Ellsworth
1-63. (and WAYLAND, R. G.) Coal in the Stone Canyon area, Monterey County, California, in Am. Assoc. Petroleum Geologists and Soc. Econ. Paleontologists and Mineralogists, Pacific Secs., Guidebook to the geology of Salinas Valley and the San Andreas fault, Ann. Spring Field Trip, May 1963, p. 88-91, 1963.
RICHARDSON, Everett Vern
1-62. (and HARRIS, D. D.) A control structure for measuring water discharge and sediment load: Art. 175 in U. S. Geol. Survey Prof. Paper 450-D, p. D182-D184, 1962.
RICHMOND, Gerald Martin
1-62. Discussion of Note 27--Morphostratigraphic units in Pleistocene stratigraphy, American Commission on Stratigraphic Nomenclature: Am. Assoc. Petroleum Geologists Bull., v. 46, no. 8, p. 1520-1521, 1962.
2-62. Three pre-Bull Lake tills in the Wind River Mountains, Wyoming: Art. 159 in U. S. Geol. Survey Prof. Paper 450-D, p. D132-D136, 1962.
1-63. Correlation of Alpine and Rocky Mountain Quaternary glaciations [abs.]: Geol. Soc. America Spec. Paper 73, p. 224, 1963.
2-63. Correlation of some glacial deposits in New Mexico: Art. 213 in U. S. Geol. Survey Prof. Paper 450-E, p. E121-E125, 1963.
RICHTER, Donald Herman
1-62. The Tenth Pacific Science Congress: Geochem. News, no. 30, p. 12, 1962.
RIGGS, Henry Chiles
1-62. (compiler) Annotated bibliography on hydrology and sedimentation, United States and Canada, 1955-58: U. S. Geol. Survey Water-Supply Paper 1546, 236 p., 1962.
1-63. Discussion of "Forecasting river runoff by coastal flow index," by D. M. Rockwood and C. E. Jencks (Am. Soc. Civil Engineers Trans. 1962, v. 127, pt. 1, p. 129-156, 1963): Am. Soc. Civil Engineers Trans. 1962, v. 127, pt. I, p. 156-158, 1963.

RILEY, Francis Stevenson
1-62. An automatic recording liquid-level tiltmeter [abs.]: Am. Geophys. Union Trans., v. 43, no. 4, p. 427-428, 1962.

RIMA, Donald Robert
1-62. (and MEISLER, Harold, and LONGWILL, S. M.) Geology and hydrology of the Stockton Formation in southeastern Pennsylvania: Pennsylvania Geol. Survey, 4th ser., Bull. W 14, 111 p., 1962. (Prepared by U. S. Geological Survey, Ground Water Branch, in coop. with Pennsylvania Geological Survey.)

ROACH, Carl Houston
1-62. (and JOHNSON, G. R., and McGRATH, J. G., and STERRETT, T. S.) Thermoluminescence investigations at Meteor Crater, Arizona: Art. 149 in U. S. Geol. Survey Prof. Paper 450-D, p. D98-D103, 1962.
2-62. (and JOHNSON, G. R., and McGRATH, J. G., and STERRETT, T. S.) Thermoluminescence investigations at Meteor Crater, Arizona, in Astrogeologic studies--Semiannual progress report, Feb. 26, 1961 to Aug. 24, 1961: U. S. Geol. Survey open-file report, p. 64-73, 1962.
1-63. (and JOHNSON, G. R., and McGRATH, J. G., and MERRITT, V. M., and STERRETT, T. S.) Thermoluminescence investigations at the Odessa meteorite craters, Texas, in Astrogeologic studies--Annual progress report, Aug. 25, 1961 to Aug. 24, 1962, Pt. B, Crater investigations: U. S.,Geol. Survey open-file report, p. 107-117, 1963.

ROBERSON, Charles Elmer
1-63. Carbonate equilibria in waters from thermal and nonthermal springs [abs.]: Geol. Soc. America Spec. Paper 73, p. 62, 1963.

ROBERTSON, Eugene Corley
1-62. The Carolina Bays and emergence of the Coastal Plain of the Carolinas and Georgia: Art. 92 in U. S. Geol. Survey Prof. Paper 450-C, p. C87-C90, 1962.
2-62. Physical properties of evaporite minerals: U. S. Geol. Survey Rept. TEI-821, open-file report, 90 p., 1962. (Report prepared for U. S. Atomic Energy Commission.)
3-62. Thermal properties of philippinites, in Astrogeologic studies--Semiannual progress report, Feb. 26, 1961 to Aug. 24, 1961: U. S. Geol. Survey open-file report, p. 63, 1962.

ROBIE, Richard Allen
1-62. Thermodynamic properties of minerals: U. S. Geol. Survey Rept. TEI-816, open-file report, 31 p., 1962. (Report prepared for U. S. Atomic Energy Commission.)
2-62. (and BETHKE, P. M.) Molar volumes and densities of minerals: U. S. Geol. Survey Rept.,TEI-822, open-file report, 30 p., 1962. (Report prepared for U. S. Atomic Energy Commission.)
1-63. (and BETHKE, P. M., and TOULMIN, M. S., and EDWARDS, J. L.) X-ray crystallographic data for minerals: U. S. Geol. Survey Rept. TEI-830, open-file report, 38 p., 1963. (Report prepared for U. S. Atomic Energy Commission.)

ROBINOVE, Charles Joseph
1-62. Ground-water studies and analog models: U. S. Geol. Survey Circ. 468, 12 p., 1962 [1963].
2-62. Improved techniques for geologic-map compilation, in Econ. Comm. Asia and Far East (ECAFE), Sub.-Comm. on Mineral Resources Devel., 2d Symposium on the Development of the Petroleum Resources of Asia and the Far East--U. S. Contr.: Washington, D. C., U. S. Dept. of the Interior, p. 94-101, 1962..
1-63. (and BERRY, D. W.) Availability of ground water in the Bear River valley, Wyoming, with a section on Chemical quality of the water, by J. G. Connor: U. S. Geol. Survey Water-Supply Paper 1539-V, p. V1-V44, 1963.
2-63. (and LANGFORD, R. H.) Geology and ground-water resources of the Greybull River-Dry Creek area, Wyoming: U. S. Geol. Survey Water-Supply Paper 1596, 88 p., 1963.

ROBINSON, Charles Sherwood
1-62. (and LEE, F. T.) Geology of the Straight Creek tunnel site, Clear Creek and Summit Counties, Colorado, and its predicted effect on tunnel construction: U. S. Geol. Survey open-file report, 41 p., 1962.
1-63. Engineering geology of the Straight Creek Tunnel Site, Colorado [abs.]: Rocky Mtn. Assoc. Geologists News Letter, Mar. 1963, p. 7, 1963.

ROBINSON, Geraldine M.
1-62. (and PETERSON, D. E.) Notes on earth fissures in southern Arizona: U. S. Geol. Survey Circ. 466, 7 p., 1962.
2-62. (and SKIBITZKE, H. E.) A formula for computing transmissibility causing maximum possible drawdown due to pumping: U. S. Geol. Survey Water-Supply Paper 1536-F, p. 175-180, 1962.

ROBINSON, Gershon Duvall
1-63. Geology of the Three Forks quadrangle, Montana, with sections on Petrography of igneous rocks, by H. F. Barnett: U. S. Geol. Survey Prof. Paper 370, 143 p., 1963.

ROBINSON, John W.
1-63. (and PRICE, Donald) Ground water in the Prineville area, Crook County, Oregon: U. S. Geol. Survey Water-Supply Paper 1619-P, p. P1-P49, 1963.

ROBINSON, Thomas William
1-62. General Hydrology Branch: Nevada Dept. Conserv. and Nat. Resources Humboldt River Research Proj., 3d Prog. Rept., p. 17-23, 1962.
2-62. Large evapotranspiration tanks for studies of water use by phreatophytes [abs.]: Am. Geophys. Union Trans., v. 43, no. 4, p. 453, 1962.

ROBISON, James H.
1-63. Preliminary results on the availability of ground water in the Imperial Valley area [California]: U. S. Geol. Survey open-file report, 4 p., 1963.

ROEDDER, Edwin Woods
1-62. Ancient fluids in crystals: Sci. American, v. 207, no. 4, p. 38-47, 1962.

ROEDDER, Edwin Woods--Continued
2-62. Studies of fluid inclusions--[Pt.] 1, Low temperature application of a dual-purpose freezing and heating stage: Econ. Geology, v. 57, no. 7, p. 1045-1061, 1962.
1-63. Studies of fluid inclusions--[Pt.] 2, Freezing data and their interpretation: Econ. Geology, v. 58, no. 2, p. 167-211, 1963.
2-63. (and INGRAM, B. L., and HALL, W. E.) Studies of fluid inclusions--[Pt.] 3, Extraction and quantitative analysis of inclusions in the milligram range: Econ. Geology, v. 58, no. 3, p. 353-374, 1963.

ROGERS, Cleaves Lincoln
1-62. (and CSERNA, Zoltan de, and OJEDA RIVERA, Jesús, and TAVERA AMEZCUA, Eugenio, and VAN VLOTEN, Roger) Tectonic framework of an area within the Sierra Madre Oriental and adjacent Mesa Central, north-central Mexico: Art. 68 in U. S. Geol. Survey Prof. Paper 450-C, p. C21-C24, 1962.
2-62. (and JASTER, M. C., compilers) Titanium in the United States, exclusive of Alaska and Hawaii: U. S. Geol. Survey Mineral Inv. Resource Map MR-29, 1962.

ROMAN, Irwin
1-63. The kernel function in the surface potential for a horizontally stratified earth: Geophysics, v. 28, no. 2, p. 232-249, 1963.

ROSE, Harry Joseph, Jr.
1-62. (and CUTTITTA, Frank, and CARRON, M. K., and FLANAGAN, F. J.) X-ray fluorescence analysis of tektites [abs.]: Jour. Geophys. Research, v. 67, no. 9, p. 3593, 1962.
1-63. (and ADLER, Isidore, and FLANAGAN, F. J.) X-ray fluorescence analysis of the light elements in rocks and minerals [abs.]: Geol. Soc. America Spec. Paper 73, p. 228, 1963.

ROSEBOOM, Eugene Holloway, Jr.
1-62. Djurleite, $Cu_{1.96}S$, a new mineral: Am. Mineralogist, v. 47, nos. 9-10, p. 1181-1184, 1962.
1-63. Co-Ni-Fe diarsenides--Compositions and cell dimensions: Am. Mineralogist, v. 48, nos. 3-4, p. 271-299, 1963.

ROSENSHEIN, Joseph Samuel
1-62. Geology of Pleistocene deposits of Lake County, Indiana: Art. 157 in U. S. Geol. Survey Prof. Paper 450-D, p. D127-D129, 1962.
2-62. Ground-water resources of northwestern Indiana, Preliminary report--Porter County: Indiana Div. Water Resources Bull. 12, 131 p., 1962. (Prepared by U. S. Geological Survey in coop. with Indiana Div. Water Resources.)
3-62. (and HUNN, J. D.) Ground-water resources of northwestern Indiana, Preliminary report--La Porte County: Indiana Div. Water Resources Bull. 13, 183 p., 1962. (Prepared by U. S. Geological Survey in coop. with Indiana Div. Water Resources.)
4-62. (and HUNN, J. D.) Ground-water resources of northwestern Indiana, Preliminary report--St. Joseph County: Indiana Div. Water Resources Bull. 15, 318 p., 1962. (Prepared by U. S. Geological Survey in coop. with Indiana Div.,Water Resources.)

ROSHOLT, John Nicholas, Jr.
1-61. Pleistocene chronology by the Pa231.Th230 method [abs.]: Internat. Assoc. Quaternary Research, 6th Cong., Warsaw, 1961, Abs. Papers, p. 180, 1961.
1-62. $Pa^{231}/Th^{230}$ dating and $O^{18}/O^{16}$ temperature analysis of core A254-BR-C: Jour. Geophys. Research, v. 67, no. 7, p. 2907-2911, 1962.
2-62. (and SHIELDS, W. R., and GARNER, E. L.) Isotopic fractionation of uranium in sandstone [abs.]: Am. Geophys. Union Trans., v. 43, no. 4, p. 449, 1962.
1-63. Uranium in sediments: U. S. Geol. Survey open-file report, 148 p., 1963.
2-63. (and SHIELDS, W. R., and GARNER, E. L.) Isotopic fractionation of uranium in sandstone: Science, v. 138, no. 3551, p. 224-226, 1963.
3-63. (and ANTAL, P. S.) Evaluation of the $Pa^{231}/U-Th^{230}/U$ method for dating Pleistocene carbonate rocks: Art. 209 in U. S. Geol. Survey Prof. Paper 450-E, p. E108-E111, 1963.

ROSS, Clarence Samuel
1-62. Pristine water in volcanic glass [abs.]: Jour.,Geophys. Research, v. 67, no. 9, p. 3593, 1962.

ROSS, Clyde Polhemus
1-63. Evolution of ideas relative to the Idaho batholith: Northwest Sci., v. 37, no. 2, p. 45-60, 1963.

ROSS, Donald Clarence
1-62. Correlation of granitic plutons across faulted Owens Valley, California: Art. 145 in U. S. Geol. Survey Prof. Paper 450-D, p. D86-D88, 1962.
2-62. Preliminary geologic map of the Independence quadrangle, Inyo County, California: U. S. Geol. Survey Mineral Inv. Field Studies Map MF-254, 1962. (Prepared in coop. with California Div. Mines and Geology.)

ROSS, Reuben James, Jr.
1-63. (and BERRY, W. B. N.) Ordovician graptolites of the Basin Ranges in California, Nevada, Utah, and Idaho: U. S. Geol. Survey Bull. 1134, 177 p., 1963.

ROSSMAN, Darwin Lucian
1-63. Geology of the eastern part of the Mount Fairweather quadrangle, Glacier Bay, Alaska: U. S. Geol. Survey Bull. 1121-K, p. K1-K57, 1963.
2-63. Geology and petrology of two stocks of layered gabbro in the Fairweather Range, Alaska: U. S. Geol. Survey Bull. 1121-F, p. F1-F50, 1963.

ROY, Sharat Kumar
1-62. (and GLASS, J. J., and HENDERSON, D. P.) The Walters meteorite: Fieldiana Geology, v. 10, no. 37, p. 539-550, 1962.

RUBIN, Meyer
1-62. The fifth international conference on Radiocarbon Dating--A news report: GeoTimes, v. 7, no. 4, p. 32, 1962.
1-63. (and LIKINS, R. C., and BERRY, E. G.) On the validity of radiocarbon dates from snail shells: Jour. Geology, v. 71, no. 1, p. 84-89, 1963.

RUBIN, Meyer --Continued
2-63. Simultaneity of glacial and pluvial episodes from $C^{14}$ chronology of the Wisconsin glaciation, in UNESCO, Changes of Climate, Rome Symposium, Oct. 1961, Proc., p. 223-228, 1963.

RUPPEL, Edward Thompson
1-62. A Pleistocene ice sheet in the northern Boulder Mountains, Jefferson, Powell, and Lewis and Clark Counties, Montana: U. S. Geol. Survey Bull. 1141-G, p. G1-G22, 1962.

RYLING, Roy W.
1-60. Ground-water potential of Mississippi County, Arkansas: Arkansas Geol. and Conserv. Comm. Water Resources Circ.,7, 87 p., 1960 [1962]. (Prepared in coop. with U. S. Geological Survey.)

SAMMEL, Edward A.
1-62. Configuration of the bedrock beneath the channel of the lower Merrimack River, Massachusetts: Art. 156 in U. S. Geol. Survey Prof. Paper 450-D, p. D125-D127, 1962.

SANDBERG, Charles Albert
1-62. Stratigraphic section of type Three Forks and Jefferson Formations at Logan, Montana: Billings Geol. Soc., 13th Ann. Field Conf., Sept. 1962, Guidebook, p. 47-50, 1962.
2-62. Correlation of Devonian and lowermost Mississippian rocks between outcrops in western and central Montana and the Williston Basin in eastern Montana [abs.]: Billings Geol. Soc., 13th Ann. Field Conf., Sept. 1962, Guidebook, p. 33-34, 1962.
3-62. Geology of the Williston basin, North Dakota, Montana, and South Dakota, with reference to subsurface disposal of radioactive wastes: U. S. Geol. Survey Rept. TEI-809, open-file report, 148 p., 1962. (Report prepared for U. S. Atomic Energy Commission.)

SANTOS, Elmer S.
1-63. Relation of ore deposits to the stratigraphy of the Ambrosia Lake area: New Mexico Bur. Mines and Mineral Resources Mem. 15, p. 53-59, 1963.

SANTOS, John F.
1-61. The need for basic data in water quality management and planning, in Water quality in the Columbia River Basin: Water Quality Conf., Pullman, Washington, Nov. 1960, Proc., p. 191-199, 1961.

SAX, Kenneth W.
1-63. Northern Nevada Reservoir Site investigation, 1962: U. S. Geol. Survey open-file report, 72 p., 1963.

SAYRE, Albert Nelson
1-62. (and SMITH, W. O.) Retention of water in silts and sands: Art. 118 in U. S. Geol. Survey Prof. Paper 450-C, p. C139-C141, 1962.

SAYRE, William Whitaker
1-63. (and GUY, H. P., and CHAMBERLAIN, A. R.) Uptake and transport of radionuclides by stream sediments: U. S. Geol. Survey Prof. Paper 433-A, p. A1-A33, 1963.

SCHALLER, Waldemar Theodore
1-62. (and VLISIDIS, A. C.) Ludwigite from the Read magnetite deposit, Stevens County, Washington: Econ. Geology, v. 57, no. 6, p. 950-953, 1962; reprinted in Washington State Div. Mines and Geology Repr. 7, 1962.

SCHLEE, John Stevens
1-63. Sandstone pipes of the Laguna area, New Mexico: Jour. Sed. Petrology, v. 33, no. 1, p. 112-123, 1963.

SCHLOCKER, Julius
1-63. Mineralogy of caprock and salt of Tatum dome, Lamar County, Mississippi [abs.]: Geol. Soc. America Spec. Paper 73, p. 232-233, 1963.

SCHMIDT, Dwight Lyman
1-63. (and FORD, A. B.) U. S. Geological Survey in the Patuxent Mountains, Antarctica: U. S. Antarctic Projects Officer Bull., v. 4, no. 8, p. 20-24, 1963.

SCHMIDT, Robert George
1-63. Preliminary geologic map and sections of the Hogan 4 Southeast quadrangle, Lewis and Clark County, Montana: U. S. Geol. Survey Misc. Geol. Inv. Map I-379, 1963.

SCHMIDT, Robert Gordon
1-62. Aeroradioactivity survey and areal geology of the Hanford Plant area, Washington and Oregon (ARMS-I): U. S. Atomic Energy Comm. Rept. CEX-59.4.11, 25 p., 1962. (Report prepared for U. S. Atomic Energy Commission, Civil Effects Test Operations series, by U. S. Geological Survey.)
2-62. (and ASAD, S. A.) Beach placers containing radioactive minerals, Bay of Bengal, East Pakistan: Art. 64 in U. S. Geol. Survey Prof. Paper 450-C, p. C12-C14, 1962.

SCHNABEL, Robert Wayne
1-63. Geology of the Burdock quadrangle, Fall River and Custer Counties, South Dakota: U. S. Geol. Survey Bull. 1063-F, p. 191-215, 1963.

SCHNEIDER, Robert
1-62. Use of thermometry in hydrogeologic studies of glacial deposits at Worthington, Minnesota: Geol. Soc. America Bull., v. 73, no. 10, p. 1305-1308, 1962.
2-62. Ground-water provinces of Brazil: U. S. Geol. Survey Water-Supply Paper 1663-A, p. A1-A14, 1962.

SCHNEIDER, William J.
1-62. (and GOODLETT, J. C.) Portrayal of drainage and vegetation on topographic maps: U. S. Geol. Survey open-file report, 63 p., 1962.

SCHOECHLE, George L.
1-63. (and MEYERHOFF, H. A.) In-service and university training of geologists and mineral engineers, in U. S. Dept. State, Natural resources--Minerals and mining, mapping and geodetic control: United Nations Conf. Application Sci. and Technology Benefit Less Developed Areas, Geneva, 1963, U. S. Papers, v. 2, p. 90-105, 1963.

SCHOELLHAMER, Jack Edward
1-62. (and YERKES, R. F., and CAMPBELL, R. H.) Preliminary geologic map of the coastal part of the Point Dume quadrangle, Los Angeles County, California: U. S. Geol. Survey open-file report, 2 sheets, 1962.

SCHOFF, Stuart Leeson
1-62. (and WINOGRAD, I. J.) Potential aquifers in carbonate rocks, Nevada Test Site, Nevada: Art. 105 in U. S. Geol. Survey Prof. Paper 450-C, p. C111-C113, 1962.

SCHOLL, David W.
1-62. Modern coastal swamp sedimentation, southwestern Florida [abs.]: Dissert. Abs., v. 23, no. 4, p. 1327-1328, 1962.

SCHOPF, James Morton
1-62. A preliminary report on plant remains and coal of the sedimentary section in the central range of the Horlick Mountains, Antarctica: Ohio State Univ. Research Found. Inst. Polar Studies Rept. 2, 61 p., 1962. (Prepared by U. S. Geological Survey in coop. with Institute Polar Studies for National Science Foundation.)
2-62. Plant microfossils for stratigraphic correlation, in Econ. Comm. Asia and Far East (ECAFE), Sub.-Comm. on Mineral Resources Devel., 2d Symposium on the Development of the Petroleum Resources of Asia and the Far East--U. S. Contr.: Washington, D. C., U. S. Dept. of the Interior, p. 44-76, 1962.

SCHULTZ, Leonard G.
1-62. Range in composition in bentonite beds [abs.]: Natl. Conf. Clays and Clay Minerals, 11th, Ottawa, 1962, Program and Abs., p. 20, 1962.
1-63. (and WRIGHT, J. C.) Bentonite beds of unusual composition in the Carmel Formation, southwest Utah: Art. 198 in U. S. Geol. Survey Prof. Paper 450-E, p. E67-E72, 1963.
2-63. Nonmontmorillonitic composition of some bentonite beds, in Clays and clay minerals, V. 11: Natl. Conf. Clays and Clay Minerals, 11th, Ottawa, 1962, Proc., p. 169-177, 1963.

SCHUMM, Stanley Alfred
1-63. Sinuosity of rivers [abs.]: Geol. Soc. America Spec. Paper 73, p. 235-236, 1963.
2-63. (and LUSBY, G. C.) Seasonal variation of infiltration capacity and runoff on hillslopes in western Colorado: Jour. Geophys. Research v. 68, no. 12, p. 3655-3666, 1963.

SCHWABROW, John R.
1-63. Supervision of operations under Federal and Indian oil and gas leases by the U. S. Geological Survey, in Rocky Mountain Mineral Law Institute, 8th Annual Report: Albany, New York, Matthew Bender and Co., Inc., p. 241-265, 1963

SCOTT, Glenn Robert
1-62. Geology of the Littleton quadrangle, Jefferson, Douglas, and Arapahoe Counties, Colorado: U. S. Geol. Survey Bull., 1121-L, p. L1-L53, 1962.
2-62. (and COBBAN, W. A.) Clioscaphites Saxitonianus (McLearn), a discrete ammonite zone in the Niobrara Formation at Pueblo, Colorado: Art. 90 in U. S. Geol. Survey Prof. Paper 450-C, p. C85, 1962.
1-63. Quaternary geology and geomorphic history of the Kassler quadrangle, Colorado: U. S. Geol. Survey Prof. Paper 421-A, p. 1-70, 1963.
2-63. Bedrock geology of the Kassler quadrangle, Colorado: U. S. Geol. Survey Prof. Paper 421-B, p. 71-125, 1963.

SCOTT, James H.
1-63. Computer analysis of gamma-ray logs: Geophysics, v. 28, no. 3, p. 457-465, 1963.

SCOTT, John C.
1-61. Geologic map of Bullock County, Ala.: Alabama Geol. Survey Map 19, modified from 1950 map by D. H. Eargle, 1961. (Prepared by U. S. Geological Survey in coop. with Alabama Geological Survey.)
1-62. Ground-water resources of Bullock County, Alabama--A reconnaissance: Alabama Geol. Survey Inf. Ser. 29, 120 p., 1962. (Prepared by U. S. Geological Survey in coop. with Alabama Geological Survey.)

SCOTT, Richard Albert
1-62. (and BARGHOORN, E. S., and PRAKASH, Uttam) Wood of Ginkgo in the Tertiary of western North America: Am. Jour. Botany, v., 49, no. 10, p. 1095-1101, 1962.

SCOTT, Robert Clyde
1-62. (and BARKER, F. B.) Data on uranium and radium in ground water in the United States, 1954 to 1957: U. S. Geol. Survey Prof. Paper 426, 115 p., 1962.

SEABER, Paul Robert
1-62. Variations in the chemical character of the water in the Englishtown Formation, New Jersey [abs.]: Dissert. Abs., v. 23, no. 2, p. 603, 1962.
1-63. Chloride concentrations of water from wells in the Atlantic Coastal Plain of New Jersey, 1923-61: U. S. Geol. Survey open-file report, 246 p., 1963.
2-63. (and GILL, H. E., and LANG, S. M.) Status of salt-water encroachment in the aquifer systems of the New Jersey Coastal Plain [abs.]: Geol. Soc. America Spec. Paper 73, p. 237, 1963; Ground Water, Jour. Natl. Water Well Assoc., v. 1, no. 2, p. 39, 1963.

SEARS, Julian Ducker
1-62. Yampa Canyon in the Uinta Mountains, Colorado: U. S. Geol. Survey Prof. Paper 374-I, p. I1-I33, 1962.

SEGERSTROM, Kenneth
1-62. Geology of south-central Hidalgo and northeastern México, Mexico: U. S. Geol. Survey Bull. 1104-C, p. 87-162, 1962.
2-62. Deflated marine terrace as a source of dune chains, Atacama Province, Chile: Art. 93 in U. S. Geol. Survey Prof. Paper 450-C, p. C91-C93, 1962.
3-62. Regional geology of the Chañarcillo silver mining district and adjacent areas, Chile: Econ. Geology, v. 57, no. 8, p. 1247-1261, 1962.
4-62. Structural effects related to hydration of anhydrite, Copiapo area, Chile: Art. 70 in U. S. Geol. Survey Prof. Paper 450-C, p. C28-C30, 1962.

SEGERSTROM, Kenneth--Continued
1-63. Matureland of northern Chile and its relationship to ore deposits: Geol. Soc. America Bull., v. 74, no. 4, p. 513-518, 1963.
2-63. High marine terraces in the caldera region of northern Chile [abs.]: Geol. Soc. America Spec. Paper 73, p. 237-238, 1963.
3-63. Valley widening and deepening processes in the high Andes of Chile [abs.]: Geol. Soc. America Spec. Paper 73, p. 238, 1963.

SENFTLE, Frank Edward
1-62. (and MARTINEZ, Prudencio, and ALEKNA, V. P.) Temperature dependence of decay time and intensity of alpha pulses in pure and thallium-activated cesium iodide: Rev. Sci. Instruments, v. 33, no. 8, p. 819-822, 1962.
2-62. (and THORPE, A. N., and CUTTITTA, Frank) Magnetic-susceptibility studies of the $Fe^{+2}$ ion in tektites and the determination of the amount of $Fe^{+2}$ and $Fe^{+3}$ [abs.]: Jour. Geophys. Research, v. 67, no. 9, p. 3597, 1962.
3-62. (and THORPE, A. N., and HOYT, Alfred) Magnetic susceptibility, electrical conductivity, and thermoluminescence of tektites and other materials, in Astrogeologic studies--Semiannual progress report, Feb. 26, 1961 to Aug. 24, 1961: U. S. Geol. Survey open-file report, p. 58-62, 1962.
1-63. (and THORPE, A. N.) Technique and interpretation of magnetic susceptibility measurements of water in normal and tumor tissues: Instrument Soc. America Trans., v. 2, no. 2, p. 117-120, 1963.

SEVER, Charles W.
1-62. Acid water in the crystalline rocks of Dawson County, Georgia: Georgia Mineral Newsletter, v. 15, nos. 3-4, p. 57-61, 1962.
2-62. (and CALLAHAN, J. T.) The temperature of the ground and ground-water, Dawson County, Georgia: Georgia Mineral Newsletter, v. 15, nos. 1-2, p. 25-28, 1962.
1-63. Geologic, hydrologic, physiographic, and geophysical data indicating a regional structure transecting the Coastal Plain of Georgia [abs.]: Geol. Soc. America Spec. Paper 73, p. 16, 1963.

SHACKLETTE, Hansford T.
1-62. Field observations of variation in Vaccinium uliginosum L.: Canadian Field-Naturalist, v. 76, no. 3, p. 162-167, 1962.
2-62. Influences of the soil on boreal and arctic plant communities: U. S. Geol. Survey open file report, 345 p., 1962.

SHAPIRO, Leonard
1-62. (and BRANNOCK, W. W.) Rapid analysis of silicate, carbonate, and phosphate rocks: U. S. Geol. Survey Bull. 1144-A, p. A1-A56, 1962.
2-62. (and ROSENBAUM, Fred) A sequential heating device for FeO determinations: Art. 100 in U. S. Geol. Survey Prof. Paper 450-C, p. C102-C103, 1962.

SHARP, William Neil
1-62. (and CAVENDER, W. S.) Geology and thorium-bearing deposits of the Lemhi Pass area, Lemhi County, Idaho, and Beaverhead County, Montana: U. S. Geol. Survey Bull. 1126, 76 p., 1962 [1963].

SHAUGHNESSY, John A.
1-63. Water quality in the Delaware River basin, New York: U. S. Geol. Survey open-file report, 62 p., 1963.

SHAW, Herbert Richard
1-62. Solubility of $H_2O$ in silicate melts, a theoretical discussion [abs.]: Jour. Geophys. Research, v. 67, no. 9, p. 3598, 1962.
1-63. Hydrogen-water vapor mixtures--Control of hydrothermal atmospheres by hydrogen osmosis: Science, v. 139, no. 3560, p. 1220-1222, 1963.

SHAWE, Daniel Reeves
1-62. Localization of the Uravan mineral belt by sedimentation: Art. 62 in U. S. Geol. Survey Prof. Paper 450-C, p. C6-C8, 1962.

SHAWE, Fred Rhodes
1-62. (and REEVES, R. G., and KRAL, V. E.) Iron ore deposits of Nevada--Pt. C, Iron ore deposits of northern Nevada: Nevada Bur. Mines Bull. 53, pt. C, p. 79-125, 1962. (Prepared in coop. with U. S. Geological Survey.)

SHELL, James Dugan
1-62. Floods of December 1961 in Mississippi and adjoining States: U. S. Geol. Survey Circ. 465, 17 p., 1962.

SHEN, John Teh-Ching
1-62. Analog techniques in synthetic hydrology [abs.]: Am. Geophys. Union Trans., v. 43, no. 4, p. 452, 1962.
1-63. An analog solution of the turbulent-diffusion equation for open-channel flow: Art. 233 in U. S. Geol. Survey Prof. Paper 450-E, p. E169-E171, 1963.
2-63. A method of determining the storage-outflow characteristics of nonlinear reservoirs: Art. 232 in U. S. Geol. Survey Prof. Paper 450-E, p. E167-E168, 1963.

SHEPPARD, Richard A.
1-63. (and DOBROVOLNY, Ernest) Mississippian-Pennsylvanian boundary in northeastern Kentucky: Art. 192 in U. S. Geol. Survey Prof. Paper 450-E, p. E45-E47, 1963.

SHERIDAN, Douglas Maynard
1-61. (and MAXWELL, C. H., and COLLIER, J. T.) Geology of the Lost Creek schroeckingerite deposits, Sweetwater County, Wyoming: U. S. Geol. Survey Bull. 1087-J, p. 391-478, 1961 [1962].

SHERWOOD, Clarence B., Jr.
1-62. (and KLEIN, Howard) Saline ground water in southern Florida [abs.]: Water Well Jour., v. 16, no. 10, p. 50, 1962; Florida Div. Water Resources and Conserv., Florida Water News, v. 4, no. 12, p. 2-3, 1962.
2-62. (and LEACH, S. D.) Hydrologic studies in the Snapper Creek Canal area, Dade County, Florida: Florida Geol. Survey Rept. Inv. 24, pt. 2, 32 p., 1962. (Prepared by U. S. Geological Survey in coop. with Central and Southern Florida Flood Control District.)

SHERWOOD, Clarence B., Jr.--Continued
1-63. (and KLEIN, Howard) Saline ground water in southern Florida: Ground Water, Jour. Natl. Water Well Assoc., v. 1, no. 2, p. 4-8, 1963.
2-63. (and KLEIN, Howard) Use of analog plotter in water-control problems: Ground Water, Jour. Natl. Water Well Assoc., v. 1, no. 1, p. 8-10, 15, 1963.

SHIELDS, William R.
1-63. (and GARNER, E. L., and HEDGE, C. E., and GOLDICH, S. S.) Survey of $Rb^{85}/Rb^{87}$ ratios in minerals: Jour. Geophys. Research, v. 68, no. 8, p. 2331-2334, 1963.

SHJELFO, Jelmer B.
1-62. (and others) Current studies of the hydrology of prairie potholes: U. S. Geol. Survey Circ. 472, 11 p., 1962 [1963]. (Other authors are H. M. Erskine, H. M. Jensen, R. S. Aro, F. A. Branson, D. M. Culbertson, and G. E. Harbeck, Jr.)

SHOEMAKER, Eugene Merle
1-62. (and ROACH, C. H., and BYERS, F. M., Jr.) Diatremes and uranium deposits in the Hopi Buttes, Arizona, in Petrologic studies--A volume in honor of A. F. Buddington: New York, New York, Geol. Soc. America, p. 327-355, 1962.
2-62. Geological reconnaissance of the New Quebec Crater, Canada, in Astrogeologic studies--Semiannual progress report, Feb. 26, 1961 to Aug. 24, 1961: U. S. Geol. Survey open-file report, p. 74-78, 1962.
3-62. Throwout calculations for the lunar crater Copernicus, in Astrogeologic studies--Semiannual progress report, Feb. 26, 1961 to Aug. 24, 1961: U. S. Geol. Survey open-file report, p. 117-124, 1962.
4-62. (and HACKMAN, R. J., and EGGLETON, R. E., and MARSHALL, C. H.) Lunar stratigraphic nomenclature, in Astrogeologic studies--Semiannual progress report, Feb. 26, 1961 to Aug. 24, 1961: U. S. Geol. Survey open-file report, p. 113-116, 1962.
5-62. (and MOORE, H. J., 2d) Telescopic visibility of ejecta produced by impact of the Ranger spacecraft on the Moon, in Astrogeologic studies--Semiannual progress report, Feb. 26, 1961 to Aug. 24, 1961: U. S. Geol. Survey open-file report, p. 93-105, 1962.
6-62. (and HACKMAN, R. J.) Stratigraphic basis for a lunar time scale, in Kopal, Zdeněk, and Mikhailov, Z. K., eds., The Moon: Internat. Astron. Union, Leningrad, Dec. 1960, Symposium 14, p. 289-300, New York, New York, Academic Press, 1962.
1-63. (and ELSTON, D. P.) Structure and history of the salt anticlines of the Paradox basin, Colorado and Utah [abs.]: Geol. Soc. America Spec. Paper 73, p. 283-284, 1963.
2-63. The Moon and planets: Am. Geophys. Union Trans., v. 44, no. 1, p. 140-141, 1963.
3-63. Astrogeology, a new horizon [abs.]: Geol. Soc. America Spec. Paper 73, p. 241, 1963.
4-63. Manned spaceflight--A challenge to geologists and geophysicists [abs.]: Am. Assoc. Petroleum Geologists Bull., v. 47, no. 2, p. 370, 1963.
5-63. Exploration of the Moon's surface: Am. Scientist, v. 51, no. 1, p. 99-130, 1963.

SHRIDE, Andrew Fletcher
1-61. Some aspects of younger Precambrian geology in southern Arizona [abs.]: Arizona Geol. Soc. Digest, v. 4, p. 192, 1961.

SIGVALDASON, Gudmundur Ernir
1-62. (and WHITE, D. E.) Hydrothermal alteration in drill holes GS-5 and GS-7, Steamboat Springs, Nevada: Art. 153 in U. S. Geol. Survey Prof. Paper 450-D, p. D113-D117, 1962.
1-63. Epidote and related minerals in two deep geothermal drill holes, Reykjavik and Hveragerdi, Iceland: Art. 200 in U. S. Geol. Survey Prof. Paper 450-E, p. E77-E79, 1963.

SILBERLING, Norman John
1-62. (and ROBERTS, Ralph Jackson) Pre-Tertiary stratigraphy and structure of northwestern Nevada: Geol. Soc. America Spec. Paper 72, 58 p., 1962.
1-63. Field guide to halobiid and monotid pelecypods of the Alaskan Triassic: U. S. Geol. Survey open-file report, 9 p., 1963.

SIMMONS, George Clarke
1-63. Canga caves in the Quadrilatero Ferrifero, Minas Gerais, Brazil: Natl. Speleol. Soc. Bull., v. 25, pt. 2, p. 66-72, 1963.

SIMON, Frederick Otto
1-62. (and GRIMALDI, F. S.) Spectrophotometric catalytic determination of small amounts of rhenium in mineralized rocks and molybdenite: Anal. Chemistry, v. 34, no. 11, p. 1361-1364, 1962.
2-62. Spectrophotometric catalytic determination of small amounts of rhenium in mineralized rocks and molybdenite: U. S. Geol. Survey open-file report, 50 p., 1962.

SIMONS, Daryl Baldwin
1-62. Discussion of "Stability of alluvial channels," by F. M. Henderson (Am. Soc. Civil Engineers Proc., v. 87, Jour. Hydraulics Div., no. HY 6, pt. 1, p. 109-138, 1961): Am. Soc. Civil Engineers Proc., v. 88, Jour. Hydraulics Div., no. HY 4, pt. 1, p. 317-323, 1962.
2-62. (and ALBERTSON, M. L.) Uniform water conveyance channels in alluvial materials: Am. Soc. Civil Engineers Proc., v. 88, Jour. Hydraulics Div., no. HY 4, pt. 1, p. 213-228, 1962. (Reply to discussion of paper, same journal, v. 86, no. HY 5, pt. 1, p. 73-99, 1960.)
3-62. (and RICHARDSON, E. V.) Forms of bed roughness in alluvial channels: Am. Soc. Civil Engineers Proc., v. 88, Jour. Hydraulics Div., no. HY 4, pt. 1, p. 237-243, 1962. (Reply to discussion of paper, same journal, v. 87, no. HY 3, pt. 1, p. 87-105, 1961.)
4-62. (and RICHARDSON, E. V., and HAUSHILD, W. L.) Depth-discharge relations in alluvial channels: Am. Soc. Civil Engineers Proc., v. 88, Jour. Hydraulics Div., no. HY 5, pt. 1, p. 57-72, 1962.
1-63. (and RICHARDSON, E. V.) Resistance to flow in alluvial channels: Am. Soc. Civil Engineers Trans. 1962, v. 127, pt. 1, p. 927-954, reply to discussions, p. 994-1006, 1963.

SIMONS, Daryl Baldwin--Continued
2-63. (and RICHARDSON, E. V., and HAUSHILD, W. L.) Some effects of fine sediment and flow phenomena: U. S. Geol. Survey Water-Supply Paper 1498-G, p. G1-G47, 1963.

SIMONS, Frank Stanton
1-62. Devitrification dikes and giant spherulites from Klondyke, Arizona: Am. Mineralogist, v. 47, nos. 7-8, p. 871-885, 1962.

SIMS, Paul Kibler
1-62. (and BARTON, P. B., Jr.) Hypogene zoning and ore genesis, Central City district, Colorado, in Petrologic studies--A volume in honor of A.F. Buddington: New York, N.Y.Geol.Soc.America, p. 373-395, 1962.

SINCLAIR, William C.
1-62. Ground-water resources of Hualapai Flat--Washoe, Pershing, and Humboldt Counties, Nevada: Nevada Dept. Conserv. and Nat. Resources, Ground-Water Resources--Reconn. Ser. Rept. 11, 15 p., 1962. (Prepared by U. S. Geological Survey in coop. with Nevada Dept. Conservation and Natural Resources.)
1-63. (and LOELTZ, O. J.) Ground-water conditions in the Fernley-Wadsworth area, Churchill, Lyon, Storey and Washoe Counties, Nevada: U. S. Geol. Survey Water-Supply Paper 1619-AA, p. AA1-AA22, 1963.

SISCO, Harold G.
1-62. (and LUSCOMBE, R. W.) Records of wells and water-level fluctuations in the Aberdeen-Springfield area, Bingham and Power Counties, Idaho, in 1961: U. S. Geol. Survey open-file report, 20 p., 1962.

SISLER, Frederick David
1-62. (and SENFTLE, F. E.) Possible influence of the earth's magnetic field on geomicrobiological processes in the hydrosphere, Chap., 16 in Oppenheimer, C. H., ed., Symposium on marine microbiology: Springfield, Illinois, Charles C. Thomas Pub. Co., p. 159-176, 1962 [1963].

SKIBITZKE, Herbert E.
1-62. Hydrologic models of ground-water movement: Arizona Watershed Symposium, 6th Ann., Sept. 18, 1962, Proc., p. 17-19, 1962.
1-63. (and ROBINSON, G. M.) Dispersion in ground water flowing through heterogeneous materials: U. S. Geol. Survey Prof. Paper 386-B, p. B1-B3, 1963.
2-63. The use of analogue computers for studies in ground-water hydrology: Inst. Water Engineers Jour. (London), v. 17, no. 3, p. 216-230, reply to discussion, p. 284-289, 1963.

SKINNER, Brian John
1-62. Thermal expansion of ten minerals: Art. 152 in U. S. Geol. Survey Prof. Paper 450-D, p. D109-D112, 1962.
2-62. (and STEWART, D. B., and MORGENSTERN, J. C.) A new heating stage for the X-ray diffractometer: Am. Mineralogist, v. 47, nos. 7-8, p. 962-967, 1962.
3-62. (and EVANS, H. T., Jr.) Discussion of "Zur thermischen Umwandlung und Kristallographie von Petalit und Spodumen," by H. Saalfeld (Zeitschr. Kristallographie, Band 115, Heft 5-6, p. 420-432, 1961): Zeitschr. Kristallographie (Frankfurt am Main, Germany), Band 117, Heft 2-3, p. 227-230, 1962.
1-63. (and APPLEMAN, D. E.) Melanophlogite, a cubic polymorph of silica [abs.]: Geol. Soc. America Spec. Paper 73, p. 245, 1963.
2-63. (and FAHEY, J. J.) Observations on the inversion of stishovite to silica glass [abs.]: Am. Geophys. Union Trans., v. 44, no. 1, p. 117-118, 1963.

SKINNER, H. Catherine W.
1-63. (and SKINNER, B. J., and RUBIN, Meyer) Age and accumulation rate of dolomite-bearing carbonate sediments in South Australia: Science, v. 139, no. 3552, p. 335-336, 1963.

SKIPP, Betty Ann Lindberg
1-63. Zonation of calcareous Foraminifera in the Redwall Limestone (Mississippian), Arizona [abs.]: Geol. Soc. America Spec. Paper 73, p. 245-246, 1963.

SKOUGSTAD, Marvin Wilmer
1-63. (and HORR, C. A.) Occurrence and distribution of strontium in natural water: U. S. Geol. Survey Water-Supply Paper 1496-D, p. 55-97, 1963.

SLAUGHTER, Turbit H.
1-62. Beach-area water supplies between Ocean City, Maryland, and Rehoboth Beach, Delaware: U. S. Geol. Survey Water-Supply Paper 1619-T, p. T1-T10, 1962.

SMITH, George Irving
1-62. Subsurface stratigraphy of late Quaternary deposits, Searles Lake, California--A summary: Art. 82 in U. S. Geol. Survey Prof. Paper 450-C, p. C65-C69, 1962.
1-63. Possible large left-lateral displacement on the Garlock fault [California] [abs.]: Pacific Petroleum Geologist, v. 17, no. 2, p. 2, 1963.

SMITH, Howard R.
1-62. Geology of the Melstone-Sumatra area in central Montana: U. S. Geol. Survey Oil and Gas Inv. Map OM-211, 1962.

SMITH, Patsy Beckstead
1-63. Quantitative and qualitative analysis of the family Bolivinidae: U. S. Geol. Survey Prof. Paper 429-A, p. A1-A39, 1963.

SMITH, Ralph Emerson
1-62. (and GATES, J. S.) Ground-water conditions in the southern and central parts of the East Shore area, Utah, 1953-61: U. S. Geol. Survey open-file report, 60 p., 1962.

SMITH, Ward Conwell
1-63. Salt deposits in desert basins of the Western United States [abs.]: Northern Ohio Geol. Soc., Symposium on Salt, Cleveland, May 1962, p. 196, 1963.

SMITH, Winchell
1-62. (and BAILEY, G. F.) Optical current meter: Am. Soc. Civil Engineers Proc., v. 88, Jour. Hydraulics Div., no. HY 5, pt. 1, p. 13-22, 1962.

SNAVELY, Parke Detweiler, Jr.
1-63. (and WAGNER, H. C.) Tertiary geologic history of western Oregon and Washington: Washington State Div. Mines and Geology Rept. Inv. 22, 25 p., 1963.
2-63. (and WAGNER, H. C.) Evolution of the Tertiary geosyncline of western Oregon and Washington [abs.]: Oregon Acad. Sci., 21st Ann. Mtg., Corvallis, Feb. 23, 1963, Abs. Papers, p. 17-18, 1963.

SNIDER, John Luther
1-62. Emergency ground-water supplies in the Monroe area, Louisiana: Baton Rouge, Louisiana Geol. Survey and Louisiana Dept. Public Works, map with tex, 1962. (Prepared in coop. with U. S. Geological Survey.)
2-62. (and WINNER, M. D., and EPSTEIN, J. B.) Ground water for Louisiana's public supplies: Baton Rouge, Louisiana Dept. Public Works, 267 p., 1962. (Prepared in coop. with U. S. Geological Survey.)

SNIEGOCKI, Richard Ted
1-63. (and BAYLEY, F. H., 3d, and ENGLER, Kyle) Equipment and controls used in studies of artificial recharge in the Grand Prairie region, Arkansas: U. S. Geol. Survey Water-Supply Paper 1615-C, p. C1-C39, 1963.

SNYDER, Charles Theodore
1-62. A hydrologic classification of valleys in the Great Basin, western United States: Internat. Assoc. Sci. Hydrology Bull. (Louvain, Belgium), 7[e] année, no. 3, p. 53-59, 1962.
1-63. Hydrology of stock-water development on the public domain of western Utah: U. S. Geol. Survey Water-Supply Paper 1475-N, p. 487-536, 1963.
2-63. Hydrology of stock-water development in the Ely Grazing District, Nevada: U. S. Geol. Survey Water-Supply Paper 1475-L, p. 383-441, 1963.

SNYDER, George Leonard
1-63. (and FRASER, G. D.) Pillowed lavas--[Pt.] 1, Intrusive layered lava pods and pillowed lavas, Unalaska Island, Alaska: U. S. Geol. Survey Prof. Paper 454-B, p. B1-B23, 1963.
2-63. (and FRASER, G. D.) Pillowed lavas--[Pt.] 2, A review of recent literature: U. S. Geol. Survey Prof. Paper 454-C, p. C1-C7, 1963.

SOHN, Israel Gregory
1-62. The Ostracode genus Cytherelloidea, a possible indicator of paleotemperature: Art. 162 in U. S. Geol. Survey Prof. Paper 450-D, p. D144-D147, 1962.
2-62. Stratigraphic significance of the Paleozoic ostracode genus Coryellina Bradfield, 1935: Jour. Paleontology, v. 36, no. 6, p. 1201-1213, 1962.
1-63. (and PECK, R. E.) Theriosynoecum wyomingense (Branson, 1935), a possible guide ostracode to the Salt Wash Member of the Morrison Formation: U. S. Geol. Survey Bulletin 1161-A, p. A1-A10, 1963.

SOUTHARD, Rupert B., Jr.
1-63. Practical considerations for rapid mapping in developing countries, in U. S. Dept. State, Natural resources--Minerals and mining, mapping and geodetic control: United Nations Conf. Application Sci. and Technology Benefit Less Developed Areas, Geneva, 1963, U. S. Papers, v. 2, p. 307-313, 1963.

SPEER, Paul Rudolph
1-63. (and GOLDEN, H. G., and PATTERSON, J. F., and others) Low-flow characteristics of streams in the Mississippi Embayment in Mississippi and Alabama: U. S. Geol. Survey open-file report, 142 p., 1963.

STAATZ, Mortimer Hay
1-63. (and ALBEE, H. F.) Preliminary geologic map of the Garns Mountain SE quadrangle, Bonneville and Teton Counties, Idaho: U. S. Geol. Survey Mineral Inv. Field Studies Map MF-262, 1963.
2-63. Geology of the beryllium deposits in the Thomas Range, Juab County, Utah: U. S. Geol. Survey Bull. 1142-M, p. M1-M36, 1963.

STACY, John R.
1-62. Shortcut method for the preparation of shaded-relief illustrations: Art. 167 in U. S. Geol. Survey Prof. Paper 450-D, p. D165, 1962.

STAGER, Harold Keith
1-63. Geology of the London SW quadrangle, Kentucky: U. S. Geol. Survey Geol. Quad Map GQ-195, 1963. (Prepared in coop. with Kentucky Geological Survey.)
2-63. Geology of the Lily quadrangle, Kentucky: U. S. Geol. Survey Geol. Quad. Map GQ-218, 1963. (Prepared in coop. with Kentucky Geological Survey.)

STALLMAN, Robert William
1-63. Calculation of resistance and error in an electric analog of steady flow through nonhomogeneous aquifers: U. S. Geol. Survey Water-Supply Paper 1544-G, p. G1-G20, 1963.
2-63. Electric analog of three-dimensional flow to wells and its application to unconfined aquifers: U. S. Geol. Survey Water-Supply Paper 1536-H, p. 205-242, 1963.
3-63. Effects of water-table conditions on water-level changes near pumping wells [abs.]: Am. Geophys. Union Trans., v. 44, no. 1, p. 46, 1963.
4-63. Orientation of axes for calculating distribution of transmissibility from water-level altitudes: Art. 231 in U. S. Geol. Survey Prof. Paper 450-E, p. E165-E166, 1963.

STARK, John Thomas
1-63. (and HAY, R. L.) Geology and petrography of volcanic rocks of the Truk Islands, East Caroline Islands: U. S. Geol. Survey Prof. Paper 409, 41 p., 1963.

STEARNS, Richard Gordon
1-62. (and MARCHER, M. V.) Late Cretaceous and subsequent structural development of the northern Mississippi Embayment area: Geol. Soc. America Bull., v. 73, no. 11, p. 1387-1394, 1962; reprinted as Tennessee Div. Geology Rept. Inv. 18, 1962.

STEVEN, Thomas August
1-63. (and RATTÉ, J. C.) Resurgent cauldrons in the Creede area, San Juan Mountains, Colorado [abs.]: Am. Geophys. Union Trans., v. 44, no. 1, p. 112-113, 1963.

STEVENS, Rollin Elbert
1-63. (and SAINSBURY, C. L., and BETTIGA, A. C.) Dissolving fluorite with solutions of aluminum salts: Art. 96 in U. S. Geol. Survey Prof. Paper 450-C, p. C98-C99, 1962.

STEWART, Frederick H.
1-63. Marine evaporites, Chap. Y in Fleischer, Michael, ed., Date of geochemistry, 6th edition: U. S. Geol. Survey Prof. Paper 440-Y, p. Y1-Y52, 1963.

STEWART, Herbert Greer, Jr.
1-62. Records of wells and other water-resources data in Polk County, Florida: U. S. Geol. Survey open-file report, 68 p., 1962.

STEWART, John Harris
1-62. Variable facies of the Chainman and Diamond Peak Formations in western White Pine County, Nevada: Art. 79 in U. S. Geol. Survey Prof. Paper 450-C, p. C57-C60, 1962.
1-63. (and ALBERS, J. P.) Volcanic center in the Silver Peak Range, Esmeralda County, Nevada [abs.]: Geol. Soc. America Spec. Paper 73, p. 68, 1963.

STEWART, Joseph William
1-62. Relation of permeability and jointing in crystalline metamorphic rocks near Jonesboro, Georgia: Art. 169 in U. S. Geol. Survey Prof. Paper 450-D, p. D168-D170, 1962.
2-62. (and BLANCHARD, H. E.) Geologic and hydrologic data relating to disposal of waste in crystalline rocks, Georgia Nuclear Laboratory, Dawson County, Georgia: U. S. Geol. Survey open-file report, 149 p., 1962.
1-63. Water-yielding potential of weathered crystalline rocks at the Georgia Nuclear Laboratory [abs.]: Geol. Soc. America Spec. Paper 73, p. 16, 1963.
2-63. Infiltration rates in weathered crystalline rocks at the Georgia Nuclear Laboratory, Dawson County, Georgia: Art. 220 in U. S. Geol. Survey Prof. Paper 450-E, p. E140-E142, 1963.

STEWART, Samuel Woods
1-62. (and PAKISER, L. C.) Crustal structure in eastern New Mexico interpreted from the GNOME explosion: Seismol. Soc. America Bull., v. 52, no. 5, p. 1017-1030, 1962.

STIEFF, Lorin Rollins
1-63. (and STERN, T. W., and EICHER, R. N.) Algebraic and graphic methods for evaluating discordant lead-isotope ages: U. S. Geol. Survey Prof. Paper 414-E, p. E1-E27, 1963.

STIPP, Thomas Franklin
1-60. (compiler) Selected bibliography, in Roswell Geol. Soc., Field trip--Northern Franklin Mountains, southern San Andres Mountains, with emphasis on Pennsylvanian stratigraphy, Nov. 1960, Guidebook, p. 157-160, 1960.

STRAKA, George C.
1-63. (and MILLER, W. A.) Graphs of ground water levels in Minnesota, 1957-1961: Minnesota Dept. Conservation, Div. Waters Bull. 18, 58 p., 1963. (Prepared by U. S. Geological Survey in coop. with Minnesota Dept. Conservation, Division of Waters.)

STRATTON, Garland
1-62. (and WHITEHEAD, H. C.) Colorimetric determination of arsenic in water with silver diethyldithiocarbamate: Am. Water Works Assoc. Jour., v. 54, no. 7, p. 861-864, 1962.

STULIK, Ronald S.
1-63. (and TWENTER, F. E.) Geology and ground water of the Luke area, Maricopa County, Arizona: U. S. Geol. Survey open-file report, 74 p., 1963.

STUMM, Erwin Charles
1-62. Silurian corals from the Moose River synclinorium, Maine, [Chap.] A in Silurian corals from Maine and Quebec: U. S. Geol. Survey Prof. Paper 430, p. 1-9, 1962 [1963].

SUMSION, Carlton T.
1-61. Description of the juniper and pinyon eradication project, Fort Apache Indian Reservation, Arizona: Arizona Geol. Soc. Digest, v. 4, p. 86, 1961.
1-63. Significance of drainage patterns relative to ground-water occurrence in three counties of western North Carolina [abs.]: Geol. Soc. America, Southeastern Sec., Ann. Mtg., Roanoke, Virginia, Apr. 1963, Program, p. 36-37, 1963.

SUNDELIUS, Harold Wesley
1-63. The Peg Claims spodumene pegmatites, Maine: Econ. Geology, v. 58, no. 1, p. 84-106, 1963.
2-63. Accretionary lapilli in rocks of the Carolina slate belt, Stanly County, North Carolina [abs.]: Geol. Soc. America, Southeastern Sec., Ann. Mtg., Roanoke, Virginia, Apr. 1963, Program, p. 37, 1963.

SWADLEY, W. C.
1-62. Geology of the Big Clifty quadrangle, Kentucky: U. S. Geol. Survey [Geol. Quad. Map] GQ-192, 1962. (Prepared in coop. with Kentucky Geological Survey.)
1-63. Geology of the Flaherty quadrangle, Kentucky: U. S. Geol. Survey Geol. Quad. Map GQ-229, 1963. (Prepared in coop. with Kentucky Geological Survey.)

SWARTZ, Joel Howard
1-62. Some physical constants for the Marshall Islands area: U. S. Geol. Survey Prof. Paper 260-AA, p. 953-989, 1962.

SWASEY, Edmund
1-63. Half-base convergent photography: Photogramm. Eng., v. 29, no. 2, p. 258-262, 1963.

SWINDEL, George Washington, Jr.
1-62. (and HODGES, A. L., Jr.) Emergency ground-water supplies in Calcasieu Parish, Louisiana: Baton Rouge, Louisiana Geol. Survey and Louisiana Dept. Public Works, map, 1962. (Prepared in coop. with U. S. Geological Survey.)
1-63. (and WILLIAMS, M. R., and GEURIN, J. W., revised by H. L. Baldwin) A layman's look at water in Alabama: U. S. Geol. Survey Water-Supply Paper 1765, 89 p., 1963.

TAILLEUR, Irvin Lorraine
1-63. (and SABLE, E. G.) Nuka Formation of Late Mississippian to Late Permian age, new formation in northern Alaska: Am. Assoc. Petroleum Geologists Bull., v. 47, no. 4, p. 632-642, 1963.

TALBOT, James L.
1-63. (and HOBBS, B. E., and WILSHIRE, H. G., and SWEATMAN, T. R.) Xenoliths and xenocrysts from lavas of the Kerguelen Archipelago: Am. Mineralogist, v. 48, nos. 1-2, p. 159-179, 1963.

TANAKA, Harry H.
1-63. (and DAVIS, L. V.) Ground-water resources of the Rush Springs Sandstone in the Caddo County area, Oklahoma: Oklahoma Geol. Survey Circ. 61, 63 p., 1963. (Prepared under a cooperative agreement between the Oklahoma Geological Survey and the U. S. Geological Survey.)

TANNER, Allan Bain
1-63. Physical and chemical controls on distribution of radium and radon in ground water near Great Salt Lake, Utah [abs.]: Internat. Symposium Natural Radiation Environment, Rice Univ., Houston, Texas, Apr. 1963, Program, p. 19, 1963.
2-63. Radon migration in the ground--A review [abs.]: Internat. Symposium Natural Radiation Environment, Rice Univ., Houston, Texas, Apr. 1963, Program, p. 22, 1963.

TAPPAN, Helen Niña
1-62. Foraminifera from the Arctic slope of Alaska--Pt. 3, Cretaceous Foraminifera: U. S. Geol. Survey Prof. Paper 236-C, p. 91-209, 1962.

TARVER, George Robert
1-63. Hydrology of the Biscayne aquifer in the Pompano Beach area, Broward County, Florida: U. S. Geol. Survey open-file report, 57 p., 1963.

TAYLOR, Alfred R.
1-62. Geology of the Amandaville quadrangle, Kentucky: U. S. Geol. Survey [Geol. Quad. Map] GQ-186, 1962. (Prepared in coop. with Kentucky Geological Survey.)

TAYLOR, Dwight Willard
1-62. (and SOHL, N. F.) An outline of gastropod classification: Malacologia, v. 1, no. 1, p. 7-32, 1962.
1-63. Mollusks of the Black Butte local fauna [Oregon], [Chap.] 3 in Shotwell, J. A., The Juntura Basin--Studies in earth history and paleoecology: Am. Philos. Soc. Trans. 1963, v. 53, pt. 1, p. 35-41, 1963.

TAYLOR, George Carroll, Jr.
1-60. (and PATHAK, B. D.) Geology and groundwater resources of the Anjar-Khedoi region, eastern Kutch, with particular reference to the Kandla Port water-supply: Geol. Survey India Bull. (Delhi), ser. B, no. 9, 339 p., 1960.

TAYLOR, Richard Bartlett
1-62. (and SIMS, P. K.) Precambrian gabbro in the central Front Range, Colorado: Art. 154 in U. S. Geol. Survey Prof. Paper 450-D, p. D118-D122, 1962.

TAYLOR, Robert Hugh, Jr.
1-63. (and BROOKS, N. H.) Discussion of "Unsteady flow of ground water into a surface reservoir," by W. L. Haushild and Gordon Kruse (Am. Soc. Civil Engineers Trans. 1962, v. 127, pt. 1, p. 408-415, 1963): Am. Soc. Civil Engineers Trans. 1962, v. 127, pt. 1, p. 982-992, 1963.

THADEN, Robert Emerson
1-62. (and LEWIS, R. Q., Sr.) Geology of the Jamestown quadrangle, Kentucky: U. S. Geol. Survey [Geol. Quad. Map] GQ-182, 1962.
1-63. (and LEWIS, R. Q., Sr.) Geology of the Creelsboro quadrangle, Kentucky: U. S. Geol. Survey Geol. Quad Map GQ-204, 1963. (Prepared in coop. with Kentucky Geological Survey.)
2-63. (and SANTOS, E. S.) Map showing the general structural features of the Grants area and the areal distribution of the known uranium ore bodies in the Morrison Formation: New Mexico Bur. Mines and Mineral Resources Mem. 15, map opposite p. 20, 1963.

THATCHER, Leland L.
1-62. New tritium fallout over North America from the 1961 USSR nuclear tests [abs.]: Jour. Geophys. Research, v. 67, no. 9, p. 3603, 1962.

THAYER, Thomas Prence
1-62. Application of structural petrology in exploration for podiform chromite deposits, in Geologists of the Federative People's Republic of Yugoslavia, 5th Mtg., Belgrad, Oct. 1962, Rept., v. 2, p. 295-303, 1962.
1-63. The magnifying single-prism stereoscope, a new field instrument: Jour. Forestry, v. 61, no. 5, p. 389-390, 1963. (Reprinted from U. S. Geol. Survey Prof. Paper 424-D, p. D386-D387, 1961.)

THEOBALD, Paul Kellogg, Jr.
1-62. (and THOMPSON, C. E.) Zinc in magnetite from alluvium and from igneous rocks associated with ore deposits: Art. 84 in U. S. Geol. Survey Prof. Paper 450-C, p. C72-C73, 1962.
2-62. Description, composition, and tenor of unconsolidated sediments in monazite-bearing tributaries to the Broad River in the western Piedmont of South Carolina and North Carolina: U. S. Geol. Survey open-file report, 18 p., 1962.
1-63. (and LAKIN, H. W., and HAWKINS, D. B.) The precipitation of aluminum, iron and manganese at the junction of Deer Creek with Snake River in Summit County, Colorado: Geochim. et Cosmochim. Acta, v. 27, no. 2, p. 121-132, 1963.

THOMAS, Cecil A.
1-62. (and LAMKE, R. D.) Floods of February 1962 in southern Idaho and northeastern Nevada: U. S. Geol. Survey Circ. 467, 30 p., 1962.
1-63. Investigation of the inflow to the Rathdrum Prairie-Spokane Valley aquifer [Idaho]: U. S. Geol. Survey open-file report, 46 p., 1963.

THOMAS, Donald Morgan
1-62. (and EDELEN, G. W., Jr.) Tidal floods, Atlantic City and vicinity, New Jersey: U. S. Geol. Survey Hydrol. Inv. Atlas HA-65, 1962.

THOMAS, Harold Edgar
1-61. (and DUTCHER, L. C.) Ground-water dilemma at Teboulba, Tunisia, in Groundwater in arid zones, Symposium of Athens, Sept. 1961, V. 2: Internat. Assoc. Sci. Hydrology (Gentbrugge, Belgium) Pub. 57, p. 597-604, 1961.
1-62. The meteorologic phenomenon of drought in the Southwest: U. S. Geol. Survey Prof. Paper 372-A, p. A1-A43, 1962.
2-62. Water and the Southwest--What is the future?: U. S. Geol. Survey Circ. 469, 15 p., 1962.
1-63. Causes of depletion of the Pecos River in New Mexico: U. S. Geol. Survey Water-Supply Paper 1619-G, p. G1-G14, 1963.
2-63. (and others) Effects of drought in the Rio Grande basin: U. S. Geol. Survey Prof. Paper 372-D, p. D1-D59, 1963.

THOMAS, Herman Hoit
1-63. Isotopic ages on coexisting hornblende, mica, and feldspar [abs.]: Am. Geophys. Union Trans., v. 44, no. 1, p. 110, 1963.

THORPE, Arthur Nathaniel
1-63. (and SENFTLE, F. E., and CUTTITTA, Frank) Magnetic and chemical investigation of iron in tektites: Nature (London), v. 197, no. 4870, p. 836-840, 1963.
2-63. (and SENFTLE, F. E., and CUTTITTA, Frank) Magnetic and chemical studies of iron in tektites [abs.]: Am. Geophys. Union Trans., v. 44, no. 1, p. 92-93, 1963.
3-63. (and SENFTLE, F. E., and CUTTITTA, Frank) Magnetic and chemical studies of iron in tektites, in Astrogeologic studies--Annual progress report, Aug. 25, 1961 to Aug. 24, 1962, Pt. C, Cosmochemistry and petrography: U. S. Geol. Survey open-file report, p. 130-149, 1963.

THURSTON, William Roberts
1-63. Geological Survey, U. S., in 1963 Britannica book of the year--A record of the march of events of 1962: Chicago, Ill., Encyclopaedia Brittanica, Inc., p. 401, 1963.

TITUS, Frank Bethel, Jr.
1-62. Ground-water conditions and geology in eastern Valencia County, New Mexico: U. S. Geol. Survey open-file report, 192 p., 1962.
1-63. Geology and ground-water conditions in eastern Valencia County, New Mexico: New Mexico Bur. Mines and Mineral Resources Ground-Water Rept. 7, 113 p., 1963. (Prepared by U. S. Geological Survey in coop. with New Mexico Institute of Mining and Technology, New Mexico State Bureau of Mines and Mineral Resources, and New Mexico State Engineer.)

TODD, Ruth
1-62. Recent literature on the Foraminifera: Cushman Found. Foram. Research Contr., v. 13, pt. 3, p. 111-117, pt. 4, p. 153-159, 1962.

TOLBERT, Gene Edward
1-62. Relação entre micas cromíferas e jazidas de ouro [abs.]: Acad. Brasileira Ciências Anais (Rio de Janeiro), v. 34, no. 4, p. xxxiii, 1962.

TOOKER, Edwin Wilson
1-62. Clay minerals in rocks of the lower part of the Oquirrh Formation, Utah, in Swineford, Ada, ed., Clays and clay minerals, V. 9: Natl. Conf. Clays and Clay Minerals, 9th, Lafayette, Indiana, Oct. 1960, Proc., p. 355-364, 1962. (Issued as Earth Science Ser. Mon. 11 of Pergamon Press by Macmillan Co., New York.)
1-63. (and ROBERTS, R. J.) Comparison of Oquirrh Formation sections in the northern and central Oquirrh Mountains, Utah [abs.]: Geol. Soc. America Spec. Paper 73, p. 99, 1963.
2-63. (and ROBERTS, R. J.) Comparison of Oquirrh Formation sections in the northern and central Oquirrh Mountains, Utah: Art. 188 in U. S. Geol. Survey Prof. Paper 450-E, p. E32-E36, 1963.

TOULMIN, Lyman Dorgan, Jr.
1-63. (and LaMOREAUX, P. E.) Stratigraphy along Chattahoochee River, connecting link between Atlantic and the Gulf Coastal Plains: Am. Assoc. Petroleum Geologists Bull., v. 47, no. 3, p. 385-404, 1963.

TOURTELOT, Harry Allison
1-63. Mineralogy and petrographic characteristics of selected samples, in Zangerl, R., The paleoecological history of two Pennsylvanian black shales [Indiana]: Fieldiana Geology Mem., v. 4, p. 100-104, Apr. 30, 1963.

TOUSIMIS, Anastasios J.
1-63. (and ADLER, Isidore) Electron probe X-ray microanalyzer study of copper within Descement's membrane of Wilson's disease: Jour. Histochemistry and Cytochemistry, v. 11, no. 1, p. 40-47, 1963.

TRACE, Robert Denny
1-62. Geology and fluorspar deposits of the Levias-Keystone and Dike-Eaton areas, Crittenden County, Kentucky: U. S. Geol. Survey Bull. 1122-E, p. E1-E26, 1962.
2-62. Geology of the Salem quadrangle, Kentucky: U. S. Geol. Survey Geol. Quad. Map GQ-206, 1962. (Prepared in coop. with Kentucky Geological Survey.)

TRAINER, Frank Wilson
1-62. (and SALVAS, E. H.) Ground-water resources of the Massena-Waddington area, St. Lawrence County, New York, with emphasis on the effect of Lake St. Lawrence on ground water: New York Water Resources Comm. Bull. GW-47, 227 p., 1962. (Prepared by U. S. Geol. Survey in coop. with Power Authority of State of New York and New York Water Resources Commission.)

TRAINER, Frank Wilson--Continued
1-63. Fracture traces in the south-central Shenandoah Valley, Virginia [abs.]: Geol. Soc. America, Southeastern Sec., Ann. Mtg., Roanoke, Virginia, Apr. 1963, Program, p. 38, 1963.

TRAPP, Henry, Jr.
1-63. Western border of the Brevard Schist belt in North Carolina [abs.]: Geol. Soc. America, Southeastern Sec., Ann. Mtg., Roanoke, Virginia, Apr. 1963, Program, p. 38-39, 1963.

TRAUGER, Frederick Dale
1-63. Geology and availability of ground water in the vicinity of Gila Cliff Dwellings National Monument, Catron County, New Mexico: U. S. Geol. Survey open-file report, 24 p., 1963.
2-63. (and BUSHMAN, F. X.) Ground water in the structural basins west of Tucumcari, Quay County, New Mexico: U. S. Geol. Survey open-file report, 313 p., 1963.

TRAUGER, George W.
1-62. (and TRAUGER, F. D.) Description of an early experiment in ground-water recharge through wells at Lindsay, California [abs.]: Jour. Geophys. Research, v. 67, no. 9, p. 3534-3535, 1962.

TREXLER, John Peter
1-62. (and WOOD, G. H., Jr., and ARNDT, H. H.) Uppermost Devonian and Lower Mississippian rocks of the western part of the Anthracite region of eastern Pennsylvania: Art. 73 in U. S. Geol. Survey Prof. Paper 450-C, p. C36-C39, 1962.

TRIMBLE, Donald Eldon
1-62. (and CARR, W. J.) Preliminary report on the stratigraphy of Paleozoic rocks southwest of Pocatello, Idaho: U. S. Geol. Survey open-file report, 16 p., 1962.

TRUESDELL, Alfred H.
1-62. Cation-sensitive electrodes as a tool in determining equilibrium in mineral-water relations [abs.]: Jour. Geophys. Research, v. 67, no. 9, p. 3604-3605, 1962.
2-62. Study of natural glasses through their behavior as membrane electrodes, Pt. 2: U. S. Geol. Survey open-file report, 43 p., 1962.

TURCAN, Alcee Nicholas, Jr.
1-62. Estimating water quality from electrical logs: Art. 116 in U. S. Geol. Survey Prof., Paper 450-C, p. C135-C136, 1962.
2-62. (and MEYER, R. R.) Alluvial aquifer in northeastern Louisiana--A large source of water: U. S. Geol. Survey Water-Supply Paper 1619-V, p. V1-V28, 1962.
1-63. Estimating the specific capacity of a well: Art. 222 in U. S. Geol. Survey Prof. Paper 450-E, p. E145-E148, 1963.

TWENTER, Floyd R.
1-62. Geology and promising areas for ground-water development in the Hualapai Indian Reservation, Arizona: U. S. Geol. Survey Water-Supply Paper 1576-A, p. A1-A37, 1962 [1963].
2-62. New fossil localities in the Verde Formation, Verde Valley, Arizona, in New Mexico Geol. Soc., Mogollon Rim region, east-central Arizona, 13th Field Conf., Oct. 1962, Guidebook, p. 109-114, 1962.
3-62. Rocks and water in Verde Valley, Arizona, in New Mexico Geol. Soc., Mogollon Rim region, east-central Arizona, 13th Field Conf., Oct. 1962, Guidebook, p. 135-139, 1962.
4-62. The significance of the volcanic rocks in the Fossil Creek area, Arizona, in New Mexico Geol. Soc., Mogollon Rim region, east-central Arizona, 13th Field Conf., Oct. 1962, Guidebook, p. 107-108, 1962.
1-63. (and METZGER, D. G.) Geology and ground water in Verde Valley of the Mogollon River region, Arizona: U. S. Geol. Survey open-file report, 344 p., 1963.

U. S. DEPARTMENT OF THE INTERIOR, Energy Policy Staff
1-63. Supplies, costs, and uses of the fossil fuels: Washington, D.C., U.S. Dept. Interior, 34 p., 25 tables, and 2 figs., Feb. 1963. (V. E. McKelvey, T. W. Hunter, H. J. Barton, J. E. Guidry, and D. C. Duncan.)

U. S. GEOLOGICAL SURVEY
1-61. Current status of Geologic Division projects, U. S. Geological Survey, in Arizona: Arizona Geol. Soc. Digest, v. 4, p. 169-174, 1961.
2-61. Map of Tuscaloosa County, Ala., showing distribution of geologic formations and ground water supplies: Alabama Geol. Survey Map 16, 1961. (Prepared by U. S. Geological Survey in coop. with Tuscaloosa County Board Revenue and Alabama Geological Survey.)
3-61. Quality of surface waters for irrigation, western United States, 1958: U. S. Geol. Survey Water-Supply Paper 1575, 177 p., 1961 [1962].
1-62. Astrogeologic studies--Semiannual progress report, February 26, 1961 to August 24, 1961: U. S. Geol. Survey open-file report, 137 p., 1962. (Report prepared for National Aeronautics and Space Administration.)
2-62. Fiscal year 1963 program, in Missouri River Basin Progress Report, Program Issue, July-September: Billings, Montana, Interior Missouri Basin Field Comm., p. P57-P87, 1962.
3-62. Floods at Fremont, California: U. S. Geol. Survey Hydrol. Inv. Atlas HA-54, 1962.
4-62. Floods at Fremont, Ohio: U. S. Geol. Survey Hydrol. Inv. Atlas HA-47, 1962.
5-62. Floods at Harrisburg, Pennsylvania: U. S. Geol. Survey Hydrol. Inv. Atlas HA-57, 1962.
6-62. Geologic and assay logs, Drillholes JD 327 and 339, Jo Dandy area, Colorado: U. S. Geol. Survey open-file report, 7 p., 1962.
7-62. Geologic map of Lauderdale County, Ala.: Alabama Geol. Survey Map 18, 1962. (Prepared by U. S. Geological Survey in coop. with Lauderdale County Board Commissioners and Alabama Geological Survey.)
8-62. Geological Survey, in Missouri River Basin Progress Report, Program Issue, July-September: Billings, Montana, Interior Missouri Basin Field Comm., p. 12-17, 1962.
9-62. Geological Survey, in Missouri River Basin Progress Report, October-December: Billings, Montana, Interior Missouri Basin Field Comm., p. 13-18, 1962.

U. S. GEOLOGICAL SURVEY--Continued

10-62. Ground-water levels in the United States, 1956-59--South-central States: U. S. Geol. Survey Water-Supply Paper 1549, 192 p., 1962.

11-62. Ground-water levels in the United States, 1956-58--Southeastern States: U. S. Geol. Survey Water-Supply Paper 1538, 202 p., 1962.

12-62. Hydrologic and geologic studies for Project Gnome--Progress report, May 1962: U. S. Atomic Energy Comm. Rept. PNE-130F, 196 p., 1962. (Report prepared for U. S. Atomic Energy Commission by U. S. Geological Survey for Project Gnome.)

13-62. Location of geologic field projects, Geologic Division, as of March 1, 1962--Sheet 1, Conterminous United States and Puerto Rico: U. S. Geol. Survey open-file report, 1962.

14-62. Monthly and yearly summaries of hydrographic data in the State of Washington, Oct. 1953 to Sept. 1960: Washington State Div. Water Resources Water-Supply Bull. 15, 385 p., 1962. (Prepared by U.S. Geological Survey in coop. with Washington State Division of Water Resources.)

15-62. Quality of surface waters of the United States, 1958, Parts 1-4, North Atlantic slope basins to St. Lawrence River basin: U. S. Geol. Survey Water-Supply Paper 1571, 773 p., 1962.

16-62. Quality of surface waters of the United States, 1958, Parts 5-6, Hudson Bay and Upper Mississippi River basins, and Missouri River basin: U. S. Geol. Survey Water-Supply Paper 1572, 365 p., 1962.

17-62. Short papers in geology and hydrology, articles 60-119--Geological Survey research 1962: U. S. Geol. Survey Prof. Paper 450-C, p. C1-C147, 1962.

18-62. Short papers in geology, hydrology, and topography, articles 120-179--Geological Survey research 1962: U. S. Geol. Survey Prof. Paper 450-D, p. D1-D195, 1962.

19-62. Surface water records of Arizona, 1961: Surface Water Br., Water Resources Div., 167 p., 1962.

20-62. Surface water records of California, 1961--V. 1, Colorado River basin, southern Great Basin and Pacific slope basins, excluding Central Valley; V. 2, Northern Great Basin and Central Valley: Surface Water Br., Water Resources Div., V. 1, p. 1-448, 1962; V. 2, p. 449-875, 1962.

21-62. Surface water records of Colorado, 1961: Surface Water Br., Water Resources Div., 327 p., 1962.

22-62. Surface water records of Connecticut, 1961: Surface Water Br., Water Resources Div., 89 p., 1962.

23-62. Surface water records of Florida, 1961--V. 1, Streams; V. 2, Lakes: Surface Water Br., Water Resources Div., V. 1, 294 p., 1962; V. 2, 113 p., 1962.

24-62. Surface water records of Idaho, 1961: Surface Water Br., Water Resources Div., 277 p., 1962.

25-62. Surface water records of Illinois, 1961: Surface Water Br., Water Resources Div., 184 p., 1962.

26-62. Surface water records of Indiana, 1961: Surface Water Br., Water Resources Div., 185 p., 1962.

27-62. Surface water records of Kansas, 1961: Surface Water Br., Water Resources Div., 165 p., 1962.

28-62. Surface water records of Kentucky, 1961: Surface Water Br., Water Resources Div., 164 p., 1962.

29-62. Surface water records of Louisiana, 1961: Surface Water Br., Water Resources Div., 166 p., 1962.

30-62. Surface water records of Maryland and Delaware, 1961: Surface Water Br., Water Resources Div., 102 p., 1962.

31-62 Surface water records of Massachusetts, New Hampshire, Rhode Island, Vermont, 1961: Surface Water Br., Water Resources Div., 184 p., 1962.

32-62. Surface water records of Minnesota, 1961: Surface Water Br., Water Resources Div., 174 p., 1962.

33-62. Surface water records of Mississippi, 1961: Surface Water Br., Water Resources Div., 110 p., 1962.

34-62. Surface water records of Missouri, 1961: Surface Water Br., Water Resources Div., 163 p., 1962.

35-62. Surface water records of Montana, 1961: Surface Water Br., Water Resources Div., 281 p., 1962.

36-62. Surface water records of Nevada, 1961: Surface Water Br., Water Resources Div., 118 p., 1962.

37-62. Surface water records of New Jersey, 1961: Surface Water Br., Water Resources Div., 117 p., 1962.

38-62. Surface water records of New Mexico, 1961: Surface Water Br., Water Resources Div., 211 p., 1962.

39-62. Surface water records of New York, 1961: Surface Water Br., Water Resources Div., 354 p., 1962.

40-62. Surface water records of Oklahoma, 1961: Surface Water Br., Water Resources Div., 176 p., 1962.

41-62. Surface water records of Oregon, 1961: Surface Water Br., Water Resources Div., 313 p., 1962.

42-62. Surface water records of Pennsylvania, 1961: Surface Water Br., Water Resources Div., 222 p., 1962.

43-62. Surface water records of South Carolina, 1961: Surface Water Br., Water Resources Div., 81 p., 1962.

44-62. Surface water records of Texas, 1961: Surface Water Br., Water Resources Div., 371 p., 1962.

45-62. Surface water records of Utah, 1961: Surface Water Br., Water Resources Div., 272 p., 1962.

46-62. Surface water records of Wyoming, 1961: Surface Water Br., Water Resources Div., 260 p., 1962.

47-62. Surface water supply of Mariana, Caroline, and Samoa Islands through June 1960: U. S. Geol. Survey Water-Supply Paper 1751, 107 p., 1962.

U. S. GEOLOGICAL SURVEY--Continued

48-62. Synopsis of geologic, hydrologic, and topographic results--Geological Survey research 1962: U. S. Geol. Survey Prof. Paper 450-A, p. A1-A257, 1962.

49-62. Topographic map of United Kingdom of Libya: U. S. Geol. Survey Misc. Geol. Inv. Map I-350 B, 1962.

50-62. Water for recreation--Values and opportunities: U. S. Outdoor Recreation Resources Rev. Comm. Study Rept. 10, 73 p., 1962.

1-63. Annual report of the Director, Geological Survey, to the Secretary of the Interior, in Annual report of the Secretary of the Interior for the fiscal year ended June 30, 1962: Washington, D. C., p. 327-362, 1963.

2-63. Surface water records of Georgia, 1962: Surface Water Br., Water Resources Div., 156 p., 1963.

3-63. Surface water records of Iowa, 1962: Surface Water Br., Water Resources Div., 152 p., 1963.

4-63. Surface water records of North Carolina, 1962: Surface Water Br., Water Resources Div., 236 p., 1963.

5-63. Surface water records of Tennessee, 1962: Surface Water Br., Water Resources Div., 145 p., 1963.

6-63. Astrogeologic studies--Annual progress report, August 25, 1961 to August 24, 1962--Pt. A, Lunar and planetary investigations; Supplement; Pt. B, Crater investigations; Pt. C, Cosmochemistry and petrography; Pt. D, Studies for space flight program; Summary: U. S. Geol. Survey open-file report, Pt. A, 66 p.; Supp., 5 sheets; Pt. B, 129 p.; Pt. C, 177 p.; Pt. D, 53 p.; Summary, 21 p., 1963.

7-63. Summary, in Astrogeologic studies--Annual progress report, Aug. 25, 1961 to Aug. 24, 1962: U. S. Geol. Survey open-file report, 21 p., 1963.

8-63. Geological Survey, in Missouri River Basin Project Report, January-March: Billings, Montana, Interior Missouri Basin Field Comm., p. 13-17, 1963.

9-63. Short papers in geology, hydrology, and topography, articles 180-239--Geological Survey research 1962: U. S. Geol. Survey Prof. Paper 450-E, p. E1-E189, 1963.

10-63. Surface water records of South Carolina, 1962: Surface Water Br., Water Resources Div., 83 p., 1963.

11-63. Surface water records of Wyoming, 1962: Surface Water Br., Water Resources Div., 270 p., 1963.

12-63. Surface water records of Louisiana, 1962: Surface Water Br., Water Resources Div., 153 p., 1963.

13-63. Surface water records of Maine, 1962: Surface Water Br., Water Resources Div., 71 p., 1963.

14-63. Surface water records of Colorado, 1962: Surface Water Br., Water Resources Div., 335 p., 1963.

15-63. Surface water records of Hawaii and other Pacific areas, 1962: Surface Water Br., Water Resources Div., 191 p., 1963.

16-63. Surface water records of Ohio, 1962: Surface Water Br., Water Resources Div., 193 p., 1963.

17-63. Surface water records of Virginia, 1962: Surface Water Br., Water Resources Div., 187 p., 1963.

18-63. Surface water records of Connecticut, 1962: Surface Water Br., Water Resources Div., 111 p., 1963.

19-63. Surface water records of Idaho, 1962: Surface Water Br., Water Resources Div., 291 p., 1963.

20-63. Surface water records of Utah, 1962: Surface Water Br., Water Resources Div., 270 p., 1963.

21-63. Mineral and water resources of Montana: U. S. Cong., 88th, 1st sess., U. S. Senate Comm. on Interior and Insular Affairs Rept., 166 p., 51 fig. (maps and charts), 1963. (Prepared in coop. with Montana Bureau of Mines and Geology.) (U. S. Geological Survey contributors were A. E. Weissenborn, C. E. Erdmann, and P. L. Weis, principal authors, and also F. C. Armstrong, Paul Averitt, A. F. Bateman, Jr., C. B. Bentley, T. F. Hanly, E. D. Jackson, C. W. Lane, W. C. Prinz, Frank Stermitz, and R. W. Swanson.)

U. S. GEOLOGICAL SURVEY, Ground-Water Branch

1-62. Extremes of flood and drought reflected in large ground-water declines in Mid-Gulf region: Florida Div. Water Resources and Conserv., Florida Water News, v. 4, no. 8, p. 2, 4, 1962.

2-62. Ground water in the Orlando area: Florida Div. Water Resources and Conserv., Florida Water News, v. 4, no. 12, p. 1, 4, 1962.

U. S. GEOLOGICAL SURVEY, Water Resources Division

1-62. U. S. Geological Survey program: Texas Water, v. 19, no. 2, p. 7-8, 1962.

VAN ALSTINE, Ralph Erskine

1-63. Investigations of the principal fluorspar districts of Mexico: U. S. Geol. Survey open-file report, 98 p., 1963.

VAN COUVERING, John A.

1-62. Characteristics of large springs in Kentucky: Kentucky Geol. Survey, ser. 10, Inf. Circ. 8, 37 p., 1962. (Prepared by U. S. Geological Survey and Kentucky Geological Survey with coop. of Kentucky Dept. Economic Development.)

van HYLCKAMA, Tinco E. A.

1-62. Use of water by salt cedar (Tamarix Pentandra) as measured by the water budget method [abs.]: Jour. Geophys. Research, v. 67, no. 9, p. 3535, 1962.

VANLIER, Kenneth Eugene

1-62. Summary of ground-water conditions in the Elsie area, Michigan: Michigan Geol. Survey Div., Prog. Rept. 25, 35 p., 1962. (Prepared by U. S. Geological Survey in coop. with Michigan Geological Survey Division.)

1-63. Reconnaissance of the ground-water resources of Alger County, Michigan: U. S. Geol. Survey open-file report, 45 p., 1963.

VARNES, David Joseph
1-63. Geology and ore deposits of the South Silverton mining area, San Juan County, Colorado: U. S. Geol. Survey Prof. Paper 378-A, p. A1-A56, 1963.
VAUDREY, Walter Christian
1-62. An investigation of floods in Hawaii with selected data on magnitude and frequency: U. S. Geol. Survey Water Resources Div., Surface Water Br., Honolulu Dist. Prog. Rept. 5, 192 p., 1962. (Prepared in coop. with Hawaii State Division of Water and Land Development and City and County of Honolulu.)
VECCHIOLI, John
1-63. Results of a pumping test conducted in Caldwell Township, Essex County, New Jersey: U. S. Geol. Survey open-file report, 6 p., 1963.
VHAY, John Stewart
1-62. Geology and mineral deposits of the area south of Telluride, Colorado: U. S. Geol. Survey Bull. 1112-G, p. 209-310, 1962 [1963].
VIG, Reuben Joseph
1-62. Geology of the unconsolidated deposits of Lake County, Indiana: U. S. Geol. Survey open-file report, 54 p., 1962.
VINE, James David
1-62. Preliminary geologic map of the Hobart and Maple Valley quadrangles, King County, Washington: Washington State Div. Mines and Geology Geol. Map GM-1, 1962. (Prepared in coop. with U. S. Geological Survey.)
1-63. Surface geology of the Nash Draw quadrangle, Eddy County, New Mexico: U. S. Geol. Survey Bull. 1141-B, p. B1-B46, 1963.
VISHER, Frank Newell
1-62. (and MINK, J. F.) Ground-water resources in southern Oahu, Hawaii: U. S. Geol. Survey open-file report, 416 p., 1962.
VITALIANO, Charles Joseph
1-63. Cenozoic geology and sections of the Ione quadrangle, Nye County, Nevada: U. S. Geol. Survey Mineral Inv. Field Studies Map MF-255, 1963.
VOEGELI, Paul Thomas, Sr.
1-62. (and HERSHEY, L. A.) Geology and ground-water resources of Prowers County, Colorado: U. S. Geol. Survey open-file report, 196 p., 1962.
1-63. Prospects for obtaining a water supply at the Moraine Park Campground site, Rocky Mountain National Park, Colorado: U. S. Geol. Survey open-file report, 16 p., 1963.
VOGEL, John David
1-62. Geology of the Cortez 2° quadrangle, Utah-Colorado: U. S. Geol. Survey open-file report, 1 map, 1962.
VORHIS, Robert Carson
1-63. Location of a major structure in the Coastal Plain of Georgia [abs.]: Geol. Soc. America Spec. Pape
WAGNER, Norman Spencer
1-63. (and BROOKS, H. C., and IMLAY, R. W.) Marine Jurassic exposures in Juniper Mountain area of eastern Oregon: Am. Assoc. Petroleum Geologists Bull., v. 47, no. 4, p. 687-701, 1963.
WAHLBERG, James S.
1-62. (and FISHMAN, M. J.) Adsorption of cesium on clay minerals: U. S. Geol. Survey Bull. 1140-A, p. A1-A30, 1962 [1963].
WAHLSTROM, Ernest Eugene
1-62. (and HORNBACK, V. Q.) Geology of the Harold D. Roberts Tunnel, Colorado--West portal to Station 468+49: Geol. Soc. America Bull., v. 73, no. 12, p. 1477-1498, 1962.
WAIT, Robert L.
1-62. Geology of the Albany West quadrangle, Georgia: U. S. Geol. Survey Misc. Geol. Inv. Map I-348, 1962. (Prepared in coop. with Georgia Dept. Mines, Mining and Geology.)
2-62. Interim report on test drilling and water sampling in the Brunswick area, Glynn County, Georgia: Georgia Geol. Survey Inf. Circ. 23, 46 p., 1962.
1-63. Geology and ground-water resources of Dougherty County, Georgia: U. S. Geol. Survey Water-Supply Paper 1539-P, p. P1-P102, 1963.
WALDRON, Howard Hamilton
1-62. Geology of Djatiluhur damsite and vicinity, West Java, Indonesia: Art. 125 in U. S. Geol. Survey Prof. Paper 450-D, p. D21-D23, 1962.
WALDROP, Henry A.
1-63. (and HYDEN, H. J.) Landslides near Gardiner, Montana: Art. 182 in U. S. Geol. Survey Prof. Paper 450-E, p. E11-E14, 1963.
WALKER, Eugene Hoffman
1-63. Ground water in the Sandpoint region, Bonner County, Idaho: U. S. Geol. Survey open-file report, 41 p., 1963.
2-63. (and SISCO, H. G.) Ground water in the Midvale and Council areas, Upper Weiser River basin, Idaho: U. S. Geol. Survey open-file report, 43 p., 1963.
WALKER, George E.
1-63. (and EAKIN, T. E.) Geology and ground water of Amargosa Desert, Nevada-California: Nevada Dept. Conserv. and Nat. Resources, Ground-Water Resources--Reconn. Ser. Rept. 14, [58] p., 1963. (Prepared by U. S. Geological Survey in coop. with Nevada Dept. Conservation and Natural Resources.)
WALKER, George Walton
1-63. (and REPENNING, C. A.) Tertiary stratigraphy of Steens Mountain area, Harney and Malheur Counties, southeastern Oregon [abs.]: Oregon Acad. Sci., 21st Ann. Mtg., Corvallis, Feb. 23, 1963, Abs. Papers, p. 18, 1963.
2-63. Reconnaissance geologic map of the eastern half of the Klamath Falls (AMS) quadrangle, Lake and Klamath Counties, Oregon: U. S. Geol. Survey Mineral Inv. Field Studies Map MF-260, 1963.
WALKER, Patrick Neil
1-62. Drainage areas at selected sites on streams in North Carolina: U. S. Geol. Survey open-file report, 67 p., 1962.
WALLACE, Robert Earl
1-63. (and TATLOCK, D. B.) An exploration possibility at the Arizona mine, Pershing County, Nevada: U. S. Geol. Survey open-file report, 12 p., 1963.
WALLER, Roger M.
1-61. (and CEDERSTROM, D. J., and TRAINER, F. W.) Data on wells in the Anchorage area, Alaska: Alaska Dept. Health and Welfare Rept., Water-Hydrol. Data, no. 14, [35] p., 1961. (Prepared by U. S. Geological Survey in coop. with Alaska Department of Health and Welfare.)
1-62. (and MATHUR, S. P.) Data on water supplies at Nome, Alaska: Alaska Dept. Health and Welfare Basic-Data Rept., Water-Hydrol. Data, no. 17, 12 p., 1962. (Prepared by U. S. Geological Survey in coop. with Alaska Department of Health and Welfare.)
2-62. (and TOLEN, D. A.) Data on ground-water exploration and development in southeastern Alaska: Alaska Dept. Health and Welfare Basic-Data Rept., Water-Hydrol. Data, no. 19, 15 p., 1962. (Prepared by U. S. Geological Survey in coop. with Alaska Department of Health and Welfare.)
3-62. (and TOLEN, D. A.) Data on wells along the Alaska Highway (State 2), Alaska: Alaska Dept. Health and Welfare Basic-Data Rept., Water-Hydrol. Data, no. 18, 26 p., 1962. (Prepared by U. S. Geological Survey in coop. with Alaska Department of Health and Welfare.)
4-62. (and TOLEN, D. A.) Data on wells and springs along the Richardson Highway (State 4), Alaska: Alaska Dept. Health and Welfare Basic-Data Rept., Water-Hydrol. Data, no. 16, 32 p., 1962. (Prepared by U. S. Geological Survey in coop. with Alaska Department of Health and Welfare.)
1-63. (and TOLEN, D. A.) Data on ground-water exploration and development in southeastern Alaska: U. S. Geol. Survey open-file report, 15 p., 1963.
2-63. (and TOLEN, D. A.) Data on wells along the Alaska Highway (State 2), Alaska: U. S. Geol. Survey open-file report, 26 p., 1963.
3-63. (and TOLEN, D. A.) Data on wells and springs along the Richardson Highway (State 4), Alaska: U. S. Geol. Survey open-file report, 31 p., 1963.
4-63. (and MATHUR, S. P.) Data on water supplies at Nome, Alaska: U. S. Geol. Survey open-file report, 12 p., 1963.
WALTERS, Kenneth Lyle
1-63. Highly productive aquifers in the Tacoma area, Washington: Art. 227 in U. S. Geol. Survey Prof. Paper 450-E, p. E157-E158, 1963.
WALTON, William Clarence
1-62. Ground-water resources of Camas Prairie, Camas and Elmore Counties, Idaho: U. S. Geol. Survey Water-Supply Paper 1609, 57 p., 1962.
WANEK, Alexander Andrew
1-63. Geologic map of the Hot Sulphur Springs NE quadrangle, Grand County, Colorado: U. S. Geol. Survey open-file report, 1963.
2-63. Geologic map of the Cooney Reservoir quadrangle, Carbon and Stillwater Counties, Montana: U. S. Geol. Survey Mineral Inv. Field Studies Map MF-265, 1963.
WARD, Frederick Norville
1-63. (and LAKIN, H. W., and CANNEY, F. C., and others) Analytical methods used in geochemical exploration by the U. S. Geological Survey: U. S. Geol. Survey Bull. 1152, 100 p., 1963.
WARD, Porter Elwood
1-63. (and TRUXES, L. S.) Water wells in Puerto Rico: U. S. Geol. Survey open-file report, 150 p., 1963.
2-63. Shallow halite deposits in the Flowerpot Shale in southwestern Oklahoma: Art. 190 in U. S. Geol. Survey Prof. Paper 450-E, p. E40-E42, 1963.
WARMAN, James C.
1-62. (and CAUSEY, L. V.) Geologic map of Calhoun County, Ala.: Alabama Geol. Survey Map 17, 1962. (Prepared by U. S. Geological Survey in coop. with Calhoun County Board Commissioners, City of Anniston, and Alabama Geological Survey.)
2-62. (and CAUSEY, L. V.) Geology and ground-water resources of Calhoun County, Alabama: Alabama Geol. Survey County Rept. 7, 77 p., 1962. (Prepared by U. S. Geological Survey in coop. with Calhoun County Board of Commissioners, City of Anniston, and Geological Survey of Alabama.)
WARREN, Charles Reynolds
1-63. Surface material of the moon: Science, v. 140, no. 3563, p. 188-190, 1963; abs., Am. Geophys. Union Trans., v. 44, no. 1, p. 75, 1963.
WASSERBURG, Gerald J.
1-63. (and EBERLEIN, G. D., and LANPHERE, M. A.) Age of the Birch Creek Schist and some batholitic intrusions in Alaska [abs.]: Geol. Soc. America Spec. Paper 73, p. 258-259, 1963.
WASSON, Billie E.
1-63. (and HARVEY, E. J.) Memorandum on the water supply at Kosciusko, Mississippi: Mississippi Board Water Comm. Bull. 63-2, 11 p., 1963. (Prepared by U. S. Geological Survey in coop. with Mississippi Board of Water Commissioners.)
2-63. Water resources of Attala County, Mississippi: Mississippi Geol. Econ. and Topog. Survey Bull. 99, p. 139-191, 1963. (Prepared by U. S. Geological Survey in coop. with Mississippi Geological, Economic and Topographical Survey and Mississippi Board of Water Commissioners.)
WATKINS, Frank A., Jr.
1-62. (and JORDAN, D. G.) Ground-water resources of west-central Indiana--Preliminary report, Clay County: Indiana Div. Water Resources Bull. 16, 309 p., 1962.
2-62. (and JORDAN, D. G.) Ground-water resources of west-central Indiana--Preliminary report, Sullivan County: Indiana Div. Water Resources Bull. 14, 345 p., 1962.

WATKINS, Joel Smith
1-62. Precambrian basement structure and lithology inferred from aeromagnetic and gravity data in eastern Tennessee and southern Kentucky: Art. 69 in U. S. Geol. Survey Prof. Paper 450-C, p. C25-C28, 1962.
2-62. (and YUVAL, Zvi) Gravity observations and Bouguer anomaly values for eastern Tennessee: U.S. Geol. Survey open-file report, 20 p., 1962.
1-63. Basement structure in the Valley and Ridge province of eastern Tennessee and its relation to exposed thrust faults [abs.]: Geol. Soc. America Spec. Paper 73, p. 259, 1963.
2-63. Simple Bouguer gravity map of Kentucky: U. S. Geol. Survey Geophys. Inv. Map GP-421, 1963.
3-63. Refraction seismic studies in the Miami River, Whitewater River, and Mill Creek Valleys, Hamilton and Butler Counties, Ohio: U. S. Geol. Survey open-file report, 9 p., 1963. (Prepared in coop. with City of Cincinnati, Miami Conservancy District, and Ohio Department of Natural Resources, Division of Water.)

WAYMAN, Cooper H.
1-62. Adsorption of anionic detergent on solid mineral surfaces: Art. 117 in U. S. Geol. Survey Prof. Paper 450-C, p. C137-C139, 1962.
2-62. (and ROBERTSON, J. B., and PAGE, H. G.) Apparatus for rapid determination of foam height: Art. 98 in U. S. Geol. Survey Prof. Paper 450-C, p. C100, 1962.
3-62. (and ROBERTSON, J. B., and PAGE, H. G.) Foaming characteristics of synthetic-detergent solutions: Art. 178 in U. S. Geol. Survey Prof. Paper 450-D, p. D188-D190, 1962.
4-62. (and ROBERTSON, J. B., and PAGE, H. G.) Surface tension of detergent solutions: Art. 179 in U. S. Geol. Survey Prof. Paper 450-D, p. D190-D192, 1962.
1-63. The malachite-azurite equilibrium in soil profiles: Soil Sci., v. 95, no. 2, p. 134-136, 1963.
2-63. An application of the Gibbs adsorption equation to detergent solutions: Art. 239 in U. S. Geol. Survey Prof. Paper 450-E, p. E184-E186, 1963.
3-63. (and ROBERTSON, J. B., and PAGE, H. G.) Adsorption of the surfactant $ABS^{35}$ on kaolinite: Art. 238 in U. S. Geol. Survey Prof. Paper 450-E, p. E181-E183, 1963.

WEDOW, Helmuth, Jr.
1-62. Covariance of stratigraphic thickness and metal intensity in the east Tennessee zinc districts [abs.]: Mining Eng., v. 14, no. 7, p. 40, 1962.
1-63. (and MARIE, J. R.) Statistical analysis of solution-collapse structures [abs.]: Geol. Soc. America, Southeastern Sec., Ann. Mtg., Roanoke, Virginia, Apr. 1963, Program, p. 40, 1963.

WEEKS, Alice Dowse
1-61. Mineralogy and geochemistry of vanadium in the Colorado Plateau: Jour. Less-Common Metals (Amsterdam), v. 3, no. 6, p. 443-450, 1961.
1-63. (and EARGLE, D. H.) Relation of diagenetic alteration and soil-forming processes to the uranium deposits of the southeast Texas Coastal Plain, in Swineford, Ada, ed., Clays and clay minerals, V. 10: Natl. Conf. Clays and Clay Minerals, 10th, Austin, Texas, Oct. 1961, Proc., p. 23-41, 1963. (Issued as Earth Science Ser. Mon. 12 of Pergamon Press by Macmillan Co., New York.)

WEEKS, Edwin P.
1-62. Hydrologic conditions in the Wheatland Flats area, Platte County, Wyoming: U. S. Geol. Survey open-file report, 143 p., 1962.

WEIR, James Elbert, Jr.
1-62. Ground-water conditions during 1962 at the Marine Corps Base, Twentynine Palms, Calif.: U.S.Geol. Survey open-file report, 42 p., 1962.
2-62. Ground-water inventory for 1961, Edwards Air Force Base, California: U. S. Geol. Survey open-file report, 54 p., 1962.
1-63. Large ripple marks caused by wind near Coyote Lake (dry), California [abs.]: Geol. Soc. America Spec. Paper 73, p. 72, 1963.

WEIST, William Godfrey, Jr.
1-62. Records, logs, and water-level measurements of selected wells, springs, and test holes, and chemical analyses of ground water in Otero and southern part of Crowley Counties, Colorado: Colorado Water Conserv. Board Basic-Data Rept. 11, 54 p., 1962. (Prepared by U. S. Geological Survey in coop. with Colorado Water Conservation Board.)

WELDER, Frank A.
1-62. (and REEVES, R. D.) Geology and ground-water resources of Uvalde County, Texas: Texas Water Comm. Bull. 6212, 252 p., 1962. (Prepared in coop. with U. S. Geological Survey and City of San Antonio.)

WELLS, John David
1-63. Preliminary geologic map of the Eldorado Springs quadrangle, Boulder and Jefferson Counties, Colorado: U. S. Geol. Survey Misc. Geol. Inv. Map I-383, 1963.

WELLS, Joseph Van Brunt
1-60. Changes in the streamflow data collection program of USGS: Am. Water Works Assoc. Jour., v. 52, no. 6, p. 735-741, 1960.

WESTFALL, Arthur O.
1-62. Surface waters of Elk Creek basin in southwestern Oklahoma: U. S. Geol. Survey open-file report, 18 p., 1962.
2-62. Surface waters of Otter Creek basin in southwestern Oklahoma: U. S. Geol. Survey open-file report, 37 p., 1962.

WHITCOMB, Harold A.
1-63. Decreasing yields of flowing wells in the vicinity of Newcastle, Weston County, Wyoming: U. S. Geol. Survey open-file report, 22 p., 1963.

WHITE, Amos McNairy
1-62. Description, composition, and tenor of unconsolidated sediments in monazite-bearing tributaries to the Catawba River in the western Piedmont of N. Car.: U.S.Geol. Survey open-file report, 17 p., 1962.

WHITE, Donald Edward
1-62. (and ROBERSON, C. E.) Sulphur Bank, California, a major hot-spring quicksilver deposit, in Petrologic studies--A volume in honor of A. F. Buddington: New York, New York, Geol. Soc. America, p. 397-428, 1962.
1-63. (and ANDERSON, E. T., and GRUBBS, D. K.) Geothermal brine well--Mile-deep drill hole may tap ore-bearing magmatic water and rocks undergoing metamorphism: Science, v. 139, no. 3558, p. 919-922, 1963.
2-63. (and HEM, J. D., and WARING, G. A.) Chemical composition of subsurface waters, Chap. F in Fleischer, Michael, ed., Data of geochemistry, 6th edition: U. S. Geol. Survey Prof. Paper 440-F, p. F1-F67, 1963.
3-63. (and WARING, G. A.) Volcanic emanations, Chap. K in Fleischer, Michael, ed., Data of geochemistry, 6th edition: U. S. Geol. Survey Prof. Paper 440-K, p. K1-K27, 1963.
4-63. (and SIGVALDASON, G. E.) Epidote in hot-spring systems, and depth of formation of propylitic epidote in epithermal ore deposits: Art. 201 in U. S. Geol. Survey Prof. Paper 450-E, p. E80-E84, 1963.

WHITE, George Willard
1-62. Multiple tills of end moraines: Art. 95 in U. S. Geol. Survey Prof. Paper 450-C, p. C96-C98, 1962.

WHITE, Max Gregg
1-63. (and MATZKO, J. J., and ASRARULLAH) A minimum program for mineral resources evaluation, in U. S. Dept. State, Natural resources--Minerals and mining, mapping and geodetic control: United Nations Conf. Application Sci. and Technology Benefit Less Developed Areas, Geneva, 1963, U. S. Papers, v. 2, p. 118-132, 1963.

WHITE, Natalie D.
1-62. (and STULIK, R. S., and others) Annual report on ground water in Arizona, spring 1961 to spring 1962: Arizona State Land Dept. Water Resources Rept. 11, 116 p., 1962. (Prepared by U. S. Geological Survey.) (Other authors are E. S. Davidson, S. G. Brown, H. C. Schwalen, W. F. Hardt, F. J. Frank, M. E. Cooley, P. W. Johnson, J. P. Akers, J. T. Hollander, and E. K. Morse.)
2-62. (and STULIK, R. S., and others) Annual report on ground water in Arizona, spring 1961 to spring 1962: U. S. Geol. Survey open-file report, 161 p., 1962.
1-63. Analysis and evaluation of available hydrologic data for San Simon basin, Cochise and Graham Counties, Arizona: U. S. Geol. Survey Water-Supply Paper 1619-DD, p. DD1-DD33, 1963.

WHITE, Walter Stanley
1-61. (and DOLL, C. G., leaders) Barre to Strafford via Bradford, Trip A-2, in New England Intercollegiate Geol. Conf., Vermont Geologic Map Centennial, 53d Ann. Mtg., Oct. 13-15, 1961, Guidebook, sec. 2, 11 p., 1961.
1-62. (and WRIGHT, J. C.) Geologic maps showing outcrops of the Nonesuch shale from Calumet to Black River, Michigan: U. S. Geol. Survey open-file report, 2 sheets, 1962.

WHITLOW, Jesse William
1-63. (and BROWN, C. E.) Geology of the Dubuque North quadrangle, Iowa-Wisconsin-Illinois: U. S. Geol. Survey Bull. 1123-C, p. 139-168, 1963.

WHITMORE, George Dewey
1-63. Modern techniques and instruments for surveys and mapping, in U. S. Dept. State, Natural resources--Minerals and mining, mapping and geodetic control: United Nations Conf. Application Sci. and Technology Benefit Less Developed Areas, Geneva, 1963, U. S. Papers, v. 2, p. 295-306, 1963.

WIARD, Leon Allen
1-62. Floods in New Mexico, magnitude and frequency: U. S. Geol. Survey Circ. 464, 13 p., 1962. (Prepared in coop. with New Mexico State Highway Dept.)

WIITALA, Sulo Werner
1-62. (and ASH, A. D.) Floods at Mount Clemens, Michigan: U. S. Geol. Survey Hydrol. Inv. Atlas HA-59, 1962 [1963].
1-63. (and NEWPORT, T. G.) Aerial observation of ice cover to locate areas of ground-water inflow to streams: Art. 223 in U. S. Geol. Survey Prof. Paper 450-E, p. E148-E149, 1963.

WILKINS, Eleanore E.
1-63. This works for us--Coordinating the map and book collections: Spec. Libraries, v. 54, no. 4, p. 226-227, 1963.

WILLDEN, Charles Ronald
1-63. General geology of the Jackson Mountains, Humboldt County, Nevada: U. S. Geol. Survey Bull. 1141-D, p. D1-D65, 1963.

WILLIAMS, James Stewart
1-62. Lake Bonneville--Geology of southern Cache Valley, Utah: U. S. Geol. Survey Prof. Paper 257-C, p. 131-152, 1962.

WILLIAMS, John Ropes
1-62. Geologic reconnaissance of the Yukon Flats district, Alaska: U. S. Geol. Survey Bulletin 1111-H, p. 289-331, 1962 [1963].

WILSON, Charles William, Jr.
1-62. (and MARCHER, M. V.) Geologic map of the Riverside quadrangle, Tennessee: Tennessee Dept. Conserv. and Commerce, Div. Geology, 1962. (Prepared in coop. with U. S. Geological Survey and Tennessee Valley Authority.)

WILSON, Harry Dennis, Jr.
1-62. Hydrologic bench marks to distinguish the effects of climate vs. Man [abs.]: Water Well Jour., v. 16, no. 10, p. 50-51, 1962; Ground Water, Jour. Natl. Water Well Assoc., v. 1, no. 2, p. 37, 1963.

WINOGRAD, Isaac Judah
1-62. Interbasin movement of ground water at the Nevada Test Site, Nevada: Art. 104 in U. S. Geol. Survey Prof. Paper 450-C, p. C108-C111, 1962.

WINSLOW, John Durfee
1-62. Effect of stream infiltration on ground-water temperatures near Schenectady, New York: Art. 111 in U. S. Geol. Survey Prof. Paper 450-C, p. C125-C128, 1962.
1-63. Ground-water temperatures, an index to stream infiltration at Schenectady, N. Y. [abs.]: Geol. Soc. America Special Paper 73, p. 264, 1963; Ground Water, Jour. Natl. Water Well Assoc., v. 1, no. 2, p. 41, 1963.
WINSLOW, Marcia Ring
1-62. Plant spores and other microfossils from Upper Devonian and Lower Mississippian rocks of Ohio: U. S. Geol. Survey Prof. Paper 364, 93 p., 1962.
WINTER, Thomas C.
1-62. Pollen sequence at Kirchner Marsh, Minnesota: Science, v. 138, no. 3539, p. 526-528, 1962.
2-62. Late- and post-glacial pollen diagrams for Kirchner Marsh, southeastern Minnesota [abs.]: Pollen et Spores (Paris), v. 4, no. 2, p. 388, 1962.
WITKIND, Irving Jerome
1-62. The night the earth shook--A guide to the Madison River Canyon earthquake area: U.S. Dept. Agriculture Misc. Pub. 907, 24p., 1962. (Prepared cooperatively by U.S. Geological Survey and U.S. Forest service.)
1-63. (and THADEN, R. E.) Geology and uranium-vanadium deposits of the Monument Valley area, Apache and Navajo Counties, Arizona, with sections on Serpentine at Garnet Ridge, by H. E. Malde and R. E. Thaden, and Mineralogy and paragenesis of the ore deposit at the Monument No. 2 and Cato Sells mines, by D. H. Johnson: U. S. Geol. Survey Bull. 1103, 171 p., 1963.
WOLFE, Edward W.
1-62. (and FORSYTH, J. L., and DOVE, G. D.) Geology of Fairfield County: Ohio Div. Geol. Survey Bull. 60, 230 p., 1962. (Chapter on groundwater resources prepared in coop. with U. S. Geological Survey and Div. Water, Ohio Dept. Natural Resources.)
WOLFE, Jack A.
1-62. A Miocene pollen sequence from the Cascade Range of northern Oregon: Art. 89 in U. S. Geol. Survey Prof. Paper 450-C, p. C81-C84, 1962.
2-62. Taxonomic correlation between plant megafossils and microfossils in Miocene floras of northwest Oregon [abs.]: Pollen et Spores (Paris), v. 4, no. 2, p. 388-389, 1962.
WOLFF, Roger G.
1-63. Structural aspects of kaolinite using infrared absorption: Am. Mineralogist, v. 48, nos. 3-4, p. 390-399, 1963.
WONES, David R.
1-62. Distribution of iron and aluminum between potassium feldspar and magnetiet [abs.]: Jour. Geophys. Research, v. 67, no. 9, p. 3610-3611, 1962.
1-63. (and APPLEMAN, D. E.) Properties of synthetic triclinic $KFeSi_3O_8$, iron-microcline, with some observations on the iron-microcline iron-sanidine transition: Jour. Petrology (Oxford, England), v. 4, no. 1, p. 131-137, 1963.
2-63. Phase equilibria of "ferriannite," $KFe_3^{+2}Fe^{+3}Si_3O_{10}(OH)_2$: Am. Jour. Sci., v. 261, no. 6, p. 581-596, 1963.
WOOD, Gordon Harry, Jr.
1-62. (and TREXLER, J. P., and ARNDT, H. H.) Pennsylvanian rocks of the southern part of the Anthracite region of eastern Pennsylvania: Art. 74 in U. S. Geol. Survey Prof. Paper 450-C, p. C39-C42, 1962.
2-62. (and TREXLER, J. P., and YELENOSKY, Andrew, and SOREN, Julian) Geology of rocks of Pennsylvanian age in the southern half of the Tremont quadrangle, Schuylkill County, Pennsylvania: U. S. Geol. Survey Bull. 1112-F, p. 181-208, 1962 [1963].
WOODWARD, Thomas H.
1-62. Chemical and physical character of surface waters of North Carolina, 1959-60: North Carolina Dept. Water Resources Div. Stream Sanitation and Hydrology Bull. 1, v. 4, 179p., 1962. (Prepared in coop. with U. S. Geological Survey.)
WOOLSON, John Robert
1-62. Seismic and gravity surveys of Naval Petroleum Reserve No. 4 and adjoining areas, Alaska: U. S. Geol. Survey Prof. Paper 304-A, p. 1-25, 1962 [1963].
WRIGHT, James Clifton
1-62. (and SHAWE, D. R., and LOHMAN, S. W.) Definition of members of Jurassic Entrada Sandstone in east-central Utah and west-central Colorado: Am. Assoc. Petroleum Geologists Bull., v. 46, no. 11, p. 2057-2070, 1962.
WRIGHT, James Clifton--Continued
1-63. (and DICKEY, D. D.) Relations of the Navajo and Carmel Formations in southwest Utah and adjoining Arizona: Art. 197 in U. S. Geol. Survey Prof. Paper 450-E, p. E63-E67, 1963.
WRIGHT, Thomas L.
1-62. The alkali feldspars of a shallow granitic batholith [Washington] [abs.]: Jour. Geophys. Research, v. 67, no. 9, p. 3611, 1962.
1-63. Variations in structural state of plagioclase from volcanic and hypabyssal rocks [abs.]: Geol. Soc. America Spec. Paper 73, p. 265, 1963.
YATES, Robert Giertz
1-62. Limestone in the Boundary, Leadpoint, Spirit and Deep Lake quadrangles of northern Stevens County: Washington State Div. Mines and Geology Bull. 48, p. 61-268, 1962.
2-62. (and OVERSTREET, W. C.) Preliminary geologic map of the northeast quarter of the Shelby quadrangle, Cleveland County, North Carolina: U. S. Geological Survey Mineral Inv. Field Studies Map MF-249, 1962.
1-63. Preliminary geologic map of the northwest quarter of the Shelby quadrangle, Cleveland and Rutherford Counties, North Carolina: U. S. Geological Survey Mineral Investigations Field Studies Map MF-258, 1963.
YOCHELSON, Ellis Leon
1-63. (and DUTRO, J. T., Jr.) Mourlonia sablei, new name for Mourlonia minuta Yochelson and Dutro 1960, not Weller 1916: Jour. Paleontology, v. 37, no. 3, p. 725, 1963.
YOST, Ivan D.
1-63. Floods of April-June 1957 in Texas and adjacent states: U. S. Geol. Survey Water-Supply Paper 1652-B, p. B1-B321, 1963.
YOTSUKURA, Nobuhiro
1-63. Measurement of sediment-laden flow by means of a circular orifice: Art. 234 in U. S. Geol. Survey Prof. Paper 450-E, p. E172-E173, 1963.
YOUNG, Loren Emitt
1-62. Floods near Fortuna, California: U. S. Geol. Survey open-file report, 7 p., 1962.
2-62. (and CLICK, D. E.) Floods from small drainage areas in California, October 1958 to September 1961: Menlo Park, California, U. S. Geol. Survey, 156 p., 1962. (Prepared in coop. with California Dept. Natural Resources.)
ZABLOCKI, Charles Joseph
1-62. Electrical and magnetic properties of a replacement-type magnetite deposit in San Bernardino County, California: Art. 150 in U. S. Geol. Survey Prof. Paper 450-D, p. D103-D104, 1962.
1-63. Some observations of earth voltages during nuclear explosions [abs.]: Soc. Explor. Geophysicists Yearbook 1963, p. 198, 1963.
ZAPP, Alfred Dexter
1-62. (and COBBAN, W. A.) Some Late Cretaceous strand lines in southern Wyoming: Art. 134 in U. S. Geol. Survey Prof. Paper 450-D, p. D52-D55, 1962.
ZEN, E-an
1-62. Problem of the thermodynamic status of the mixed-layer minerals: Geochim. et Cosmochim. Acta, v. 26, p. 1055-1067, 1962.
1-63. Age and classification of some Taconic stratigraphic units on the Centennial Geologic Map of Vermont--A discussion: Am. Jour. Sci., v. 261, no. 1, p. 92-94, 1963.
ZIMMERMAN, Everett Alfred
1-62. Preliminary report on the geology and ground-water resources of the southern Judith Basin, Montana: Montana Bur. Mines and Geology Bull. 32, 23 p., 1962. (Prepared by U. S. Geological Survey in coop. with Montana Bureau Mines and Geology.)
1-63. Geology and water resources of Bluewater Springs area, Carbon County, Montana: U. S. Geol. Survey open-file report, 76 p., 1963.
ZONES, Christie Paul
1-63. Preliminary report on the ground-water resources of the Waianae area, Oahu, Hawaii: Hawaii Div. Water and Land Devel. Circ. C16, 12 p., 1963. (Prepared by U. S. Geological Survey in coop. with Hawaii Division of Water and Land Development, Department of Land and Natural Resources.)
2-63. Ground water in the alluvium of Kings River Valley, Humboldt County, Nevada: U. S. Geol. Survey Water-Supply Paper 1619-L, p. L1-L38, 1963.

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# COOPERATING AGENCIES FOR FISCAL YEAR 1963

## FEDERAL AGENCIES

Agency for International Development
Air Force:
- Ballistic Systems Division
- Cambridge Research Center
- Technical Application Center

Army:
- U.S. Army—Europe
- Corps of Engineers

Atomic Energy Commission:
- Division of Biology and Medicine
- Division of Isotope Development
- Division of Reactor Development
- Military Application Division
- Nevada Operations Office
- Research Division
- San Francisco Operations Office
- Special Projects Division

Department of Agriculture:
- Agricultural Research Service
- Forest Service
- Soil Conservation Service

Department of Commerce:
- Bureau of Public Roads
- Weather Bureau

Department of Defense:
- Advanced Research Projects Agency
- Defense Intelligence Agency
- Office of Scientific Research

Department of Health, Education, and Welfare:
- Public Health Service

Department of the Interior:
- Bonneville Power Administration
- Bureau of Commercial Fisheries
- Bureau of Indian Affairs
- Bureau of Land Management
- Bureau of Mines
- Bureau of Reclamation
- Bureau of Sport Fisheries and Wildlife
- National Park Service
- Office of Minerals Exploration

Department of Justice
Department of State
District of Columbia
Federal Housing Administration
Federal Power Commission
Navy:
- Bureau of Yards and Docks
- Office of Naval Research

National Aeronautics and Space Administration
National Science Foundation
Tennessee Valley Authority

## STATE, COUNTY, AND MUNICIPAL AGENCIES

Alabama:
- Alabama State Hospitals
- Geological Survey of Alabama
- Alabama Highway Department
- Department of Conservation
- Water Improvement Commission
- Calhoun County Board of Revenue
- Mobile County
- Tuscaloosa County Board of Revenue
- City of Huntsville
- City of Russellville Water Board

Alaska:
- Department of Health
- Department of Highways

Arizona:
- Arizona Highway Department
- State Land Department
- Regents of the University of Arizona
- Superior Court, County of Apache, Arizona
- Maricopa County Flood Control District
- Maricopa County Municipal Water Conservation District No. 1
- City of Flagstaff
- City of Tucson
- City of Williams
- Navajo Tribal Council
- Buckeye Irrigation Company
- Gila Valley Irrigation District
- Salt River Valley Water Users Association
- San Carlos Irrigation and Drainage District

Arkansas:
- Arkansas Game and Fish Commission
- Arkansas Geological Commission
- Arkansas State Highway Commission
- University of Arkansas:
  - Agricultural Experiment Station
  - Engineering Experiment Station

California:
- Department of Conservation, Division of Mines and Geology
- State Department of Fish and Game
- State Department of Water Resources
- Alameda County Water District
- Calaveras County Water District

California—Continued
- County of Los Angeles, Department of County Engineers
- Montecito County Water District
- Monterey County Flood Control and Water Conservation District
- Orange County Flood Control District
- San Benito County
- San Barbara County Water Agency
- Santa Clara County Flood Control and Water Conservation District
- Santa Cruz County Flood Control and Water Conservation District
- City of Arcata
- City of San Diego
- San Francisco Water Department
- San Luis Obispo Flood Control and Water Conservation District
- Santa Barbara Water Department
- East Bay Municipal Utility District
- Georgetown Divide Public Utility District
- Hetch Hetchy Water Supply
- Lake County Flood Control and Water Conservation District
- Antelope Valley-East Kern Water Agency
- Imperial Irrigation District
- Metropolitan Water District of Southern California
- Palo Verde Irrigation District
- San Bernardino Valley Water Conservation District
- Santa Maria Valley Water Conservation District
- Ventura River Municipal Water District

Colorado:
- Department of Natural Resources
- Office of State Engineer, Division of Water Resources
- Colorado State Metal Mining Fund Board
- Colorado Water Conservation Board
- Colorado Agricultural Experiment Station
- Board of County Commissioners, Boulder County
- Colorado Springs—Department of Public Utilities
- Denver Board of Water Commissioners
- Arkansas River Compact Administration
- Colorado River Water Conservation District
- Rio Grande Compact Commission
- Southeastern Colorado Water Conservancy District
- Costilla Creek Compact Commission

Connecticut:
- Connecticut Geological and Natural History Survey
- State Highway Department
- State Water Resources Commission
- Greater Hartford Flood Commission
- Hartford Department of Public Works
- New Britain Board of Water Commissioners
- Engineering Department—City of Torrington

Delaware:
- Delaware Geological Survey
- State Highway Department

District of Columbia:
- District of Columbia Department of Sanitary Engineering

Florida:
- Florida Geological Survey
- State Board of Parks and Historic Memorials
- State Road Department
- Broward County—Board of County Commissioners
- Collier County—Board of County Commissioners
- Dade County—Board of County Commissioners
- Hillsborough County—Board of County Commissioners

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- Orange County—Board of County Commissioners
- Pinellas County—Board of County Commissioners
- Polk County—Board of County Commissioners
- City of Fort Lauderdale
- City of Jacksonville, Office of the City Engineer
- City of Jacksonville, City Commission
- City of Miami—Department of Water and Sewerage
- City of Miami Beach
- City of Naples
- City of Perry
- City of Pompano Beach
- City of Tallahassee
- Central and Southern Florida Flood Control District
- Trustees of Internal Improvement Fund

Georgia:
- State Division of Conservation, Department of Mines, Mining and Geology
- State Highway Department

Hawaii:
- State Department of Land and Natural Resources
- Honolulu, City and County of

Idaho:
- Idaho Department of Highways
- Idaho Department of Reclamation
- Idaho Department of Fish and Game

Illinois:
- State Department of Public Works and Buildings:
  - Division of Highways
  - Division of Waterways
- State Department of Registration and Education
- Cook County Department of Highways
- Fountain Head Drainage District
- Northwest Illinois Metropolitan Planning Commission

Indiana:
- State Department of Conservation—Division of Water Resources
- State Highway Commission

Iowa:
- Iowa Geological Survey
- Iowa State Conservation Commission
- Iowa Natural Resources Council
- Iowa State Highway Commission
- Iowa Institute of Hydraulic Research
- Iowa State University—Agricultural Experiment Station
- Linn County—Board of Supervisors
- City of Fort Dodge—Department of Utilities
- City of Cedar Rapids

Kansas:
- State Geological Survey of Kansas
- State Board of Agriculture, Division of Water Resources
- State Department of Health
- State Highway Commission
- State Water Resources Board
- City of Wichita:
  - Water Supply and Sewage Treatment Division
  - Metropolitan Area Planning Department

Kentucky:
- Kentucky Geological Survey

Louisiana:
- State Department of Conservation
- State Department of Highways
- State Department of Public Works
- Sabine River Compact Commission

Maine:
- Maine Public Utilities Commission
- State Highway Commission

Maryland:
- State Department of Geology, Mines, and Water Resources
- Commissioners of Charles County
- City of Baltimore
- Washington Suburban Sanitary Commission
- City of Salisbury

Massachusetts:
- State Department of Public Works:
  - Division of Waterways
  - Division of Highways
- Massachusetts Water Resources Commission
- Boston Metropolitan District Commission

Michigan:
- Department of Conservation, Geological Survey Division
- State Highway Department
- State Water Resource Commission

Minnesota:
- State Department of Conservation, Division of Waters
- State of Minnesota Department of Highways
- Board of County Commissioners of Hennepin County
- Department of Iron Range Resources and Rehabilitation

Mississippi:
- Mississippi Board of Water Commissioners
- Mississippi State Highway Department
- Jackon County, Mississippi, Port Authority
- City of Corinth
- City of Jackson
- Mississippi Industrial and Technological Research Commission
- Pearl River Valley Water Supply District

Missouri:
- Division of Geological Survey and Water Resources
- Missouri State Highway Commission
- Curators of the University of Missouri
- Water Pollution Control Board

Montana:
- Montana Bureau of Mines and Geology
- State Engineer
- State Fish and Game Commission
- State Highway Commission
- State Water Conservation Board

Nebraska:
- Department of Water Resources
- Department of Roads
- University of Nebraska—Conservation and Survey Division
- Nebraska Mid-State Reclamation District
- Sanitary District Number One of Lancaster County

Nevada:
- Nevada Bureau of Mines
- Department of Conservation and Natural Resources
- Department of Highways

New Hampshire:
- New Hampshire Water Resources Board

New Jersey:
- Department of Agriculture
- State Department of Conservation and Economic Development
- Department of Health
- Rutgers University, the State University of New Jersey
- North Jersey District Water Supply Commission

New Jersey—Continued
- Passaic Valley Water Commission
- Delaware River Basin Commission

New Mexico:
- State Engineer and School of Mines
- State Highway Department
- New Mexico Institute of Mining and Technology
- Interstate Stream Commission
- Pecos River Commission
- Pecos Valley Artesian Conservation District
- Rio Grande Compact Commission
- Costilla Creek Compact Commission

New York:
- State Conservation Department
- State Department of Commerce
- State Department of Health
- State Department of Public Works
- New York Water Resources Commission
- Office of Atomic Development
- Board of Hudson River–Black River Regulating District
- County of Dutchess—Dutchess County Board of Supervisors
- County of Nassau—Department of Public Works
- Onondaga County Public Works Commission
- Onondaga County Water Authority
- Rockland County Board of Supervisors
- Suffolk County Board of Supervisors
- County of Suffolk—Suffolk County Water Authority
- County of Westchester—Department of Public Works
- City of Albany—Department of Water and Water Supply
- City of Auburn—Water Department
- City of Jamestown—Board of Public Utilities
- New York City Board of Water Supply
- New York City Department of Water Supply; Gas and Electricity
- Village of Nyack—Board of Water Commissioners
- Schenectady Water Department
- Brighton Sewer District No. 2
- Oswegatchie-Cranberry Reservoir Commission

North Carolina:
- North Carolina Department of Conservation and Development
- State Department of Water Resources
- State Highway Commission
- Martin County—Board of County Commissioners
- City of Asheville
- City of Burlington
- City of Carey
- City of Charlotte
- City of Durham
- City of Greensboro
- City of Waynesville

North Dakota:
- North Dakota Geological Survey
- State Highway Department
- State Water Conservation Commission

Ohio:
- Ohio Department of Health
- Ohio Department of Highways
- Ohio Department of Natural Resources:
  - Division of Geological Survey
  - Division of Water
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- City of Columbus—Department of Public Service
- Miami Conservancy District
- Ohio River Valley Water Sanitation Commission
- Scioto Conservancy District

Oklahoma:
- Oklahoma State Department of Health
- Oklahoma Water Resources Board
- Oklahoma City Water Department
- Fort Cobb Reservoir Master Conservancy District

Oregon:
- State Engineer
- State Highway Department
- Board of Higher Education
- Oregon State University—Department of Fish and Game Management
- Oregon State Sanitary Authority
- Oregon Water Resources Department
- County Court of Douglas County
- Burnt River Irrigation District
- County Court of Josephine County
- County Court of Lane County
- County Court of Murrow County
- City of Dallas
- City of Dalles City
- City of Eugene—Water and Electric Board
- City of McMinnville—Water and Light Department
- City of Portland—Bureau of Water Works
- City of Toledo
- Coos Bay North Bend Water Board
- Talent Irrigation District

Pennsylvania:
- Department of Internal Affairs, Bureau of Topographic and Geologic Survey
- State Department of Agriculture
- State Department of Forests and Waters
- State Department of Health
- City of Bethlehem
- City of Harrisburg
- City of Philadelphia
- Conestoga Valley Association, Inc.

Rhode Island:
- Rhode Island Water Resources Coordinating Board
- Department of Public Works—Division of Harbors and Rivers

South Carolina:
- State Development Board
- State Highway Department
- State Public Service Authority
- State Water Pollution Control Authority
- City of Spartanburg—Public Works Department

South Dakota:
- State Geological Survey
- South Dakota Department of Highways
- South Dakota Water Resources Commission

Tennessee:
- Tennessee Department of Conservation and Commerce:
  - Division of Geology
  - Division of Water Resources
- Tennessee Game and Fish Commission
- Tennessee Department of Highways and Public Works
- Tennessee Department of Public Health—Stream Pollution Control

Tennessee—Continued
- City of Chattanooga
- Memphis Board of Light, Gas, and Water Commissioners, Water Division

Texas:
- Texas A and M Research Foundation
- Texas Water Commission
- Pecos River Commission
- Rio Grande Compact Commission
- Sabine River Compact Administration
- City of Dallas

Utah:
- Utah State Engineer
- Utah Water and Power Board
- State Department of Fish and Game
- State Road Commission of Utah
- University of Utah
- Salt Lake County
- Bear River Compact Commission

Vermont:
- State Water Resources Board
- Department of Highways

Virginia:
- Department of Conservation and Economic Development, Division of Mineral Resources
- Department of Highways
- County of Chesterfield
- Potomac River Basin Commission
- County of Fairfax
- City of Alexandria
- City of Charlottesville
- City of Newport News—Department of Public Utilities
- City of Norfolk—Division of Water Supply
- City of Roanoke
- City of Staunton

Washington:
- State Department of Conservation:
  - Division of Mines and Geology
  - Division of Water Resources
- State Department of Fisheries
- State Department of Game
- State Department of Highways
- State Pollution Control Commission
- King County Board of Commissioners
- Municipality of Metropolitan Seattle
- City of Seattle
- City of Tacoma

West Virginia:
- State Department of Natural Resources
- State Geological and Economic Survey
- State Road Commission
- State Water Resources Commission
- Clarksburg Water Board

Wisconsin:
- Wisconsin Geological and Natural History Survey
- State Highway Commission
- Public Service Commission of Wisconsin
- State Committee on Water Pollution
- Madison Metropolitan Sewerage District

Wyoming:
- Geological Survey of Wyoming
- State Engineer's Office
- Wyoming Highway Department

Wyoming—Continued
- Wyoming Natural Resource Board
- City of Cheyenne—Board of Public Utilities

Commonwealth:
- Puerto Rico:
  - Department of Public Works
  - Economic Development Administration
  - Water Resources Authority

Unincorporated Territories:
- American Samoa:
  - Government of American Samoa
- Guam:
  - Government of Guam
- Virgin Islands of the United States:
  - Government of the Virgin Islands

# U.S. GEOLOGICAL SURVEY OFFICES

## MAIN CENTERS

Main Office: General Services Building, 18th and F Streets NW., Washington, D.C., 20242; 343–1100.
Rocky Mountain Center: Federal Center, Denver, Colo., 80225; Belmont 3–3611.
Pacific Coast Center: 345 Middlefield Road, Menlo Park, Calif., 94025; Davenport 5–6761.

## PUBLIC INQUIRIES OFFICES

| *Location* | *Official in charge and telephone number* | *Address* |
|---|---|---|
| Alaska, Anchorage, 99501 | Margaret I. Erwin (Broadway 2–8791) | 503 Cordova Building. |
| California, Los Angeles, 90014 | Lucy E. Birdsall (688–2850) | 1031 Bartlett Building, 215 West 7th Street. |
| California, San Francisco, 94111 | Jean V. Molleskog (Yukon 6–3111, ext. 481) | 232 Appraisers Building. |
| Colorado, Denver, 80202 | Lorene C. Young (Keystone 4–4151, ext. 379) | 468 New Custom House. |
| Utah, Salt Lake City, 84101 | Maurine Clifford (Davis 8–2911, ext. 428) | 437 Federal Building. |
| Texas, Dallas, 75202 | Mary E. Reid (Riverside 8–5611, ext. 3230) | Room 602 Thomas Building, 1314 Wood Street. |
| Washington, Spokane, 99204 | Eva M. Raymond (Temple 8–2084, ext. 30) | South 157 Howard Street. |

## SELECTED FIELD OFFICES IN THE UNITED STATES AND PUERTO RICO

[Temporary offices not included; list current as of September 16, 1963]

## *CONSERVATION DIVISION*

| *Location* | *Official in charge* * *and telephone number* | *Address* |
|---|---|---|
| Alaska, Anchorage, 99501 | Leo H. Saarela (m), (Broadway 2–8262), Alexander A. Wanek (c), (Broadway 8–2794), and Merwin H. Soyster (o), (Broadway 5–0511) | P.O. Box 259; Rm. 507 Cordova Building, 555 Cordova Street. |
| California, Los Angeles, 90014 | Russell G. Wayland (c), and Leroy G. Snow (o), (688–2849) | 1012 Bartlett Building, 215 West 7th Street. |
| California, Sacramento, 95814 | Richard N. Doolittle (w) (449–2203) | 8030 Federal Building, 650 Capitol Avenue. |
| California, Taft, 93268 | Robert F. Evans (o) (Roger 5–4234) | P.O. Box CC. |
| Colorado, Denver, 80202 | G. G. Frazier (o) (Keystone 4–4151 Ext. 356) | 448 New Custom House. |
| Colorado, Denver, 80202 | H. B. Lindeman (m) (534–4151 Ext. 1–278) | 456 New Custom House. |
| Colorado, Denver, 80225 | George H. Horn (c) (303 233–3611 Ext. 8168) | Denver Federal Center. |
| Colorado, Denver, 80202 | Wm. C. Senkpiel (w) (Keystone 4–4151 Ext. 389) | 816 University Building, 910 16th Street. |
| Colorado, Durango, 81300 | Jerry W. Long (o) (247–5144) | P.O. Box 1809, Jarvis Building, 125 West 10th Street. |
| Louisiana, New Orleans, 70112 | Admiral D. Acuff (o) (529–2411 Ext. 6543) | T–6009 Federal Building, 701 Loyola Avenue. |
| Louisiana, Lafayette, 70500 | Robert M. Bennett (b) (Center 4–1637) | P.O. Box 3884; 301 Federal Building, Jefferson and Main Streets. |
| Montana, Billings, 59100 | Ray M. Bottomley (m) (252–2280) | 323 Federal Building; P.O. Box 2250. |

*The small letter in parentheses following each official's name denotes branch affiliation in the Conservation Division as follows: b—Branch of Connally Act Compliance, c—Branch of Mineral Classification, m—Branch of Mining Operations, o—Branch of Oil and Gas Operations, w—Branch of Waterpower Classification.

| *Location* | *Official in charge and telephone number* | *Address* |
|---|---|---|
| Montana, Billings, 59100 | Hillary A. Oden (o) (252–2880) | 327 Federal Building; P.O. Box 1435. |
| Montana, Great Falls, 59400 | Andrew F. Bateman (c) (452–2008) | 510 First Avenue North; P.O. Box 2265. |
| Montana, Great Falls, 59400 | John A. Fraher (o) (453–6901) | 510 First Avenue North; P.O. Box 1215. |
| New Mexico, Artesia, 88210 | James A. Knauf (o) (746–4841) | 210 Carper Building, 105 South 4th Street; Drawer U. |
| New Mexico, Carlsbad, 88220 | Robert S. Fulton (m) and Bruno R. Alto (c). (Tuxedo 5–6454) | 504A No. Canal Street; Box 1716. |
| New Mexico, Farmington, 87401 | Philip T. McGrath (o) (325–4572) | Box 959; Petroleum Club Plaza Building, 3535 E. 30th Street. |
| New Mexico, Hobbs, 88240 | Arthur R. Brown (o) (Express 3–3612) | 205 No. Linam Street; Box 1157. |
| New Mexico, Roswell, 88201 | J. A. Anderson (o) and T. F. Stipp (c), (622–1332) | Farnsworth Building, 120 W. 2nd Street; P.O. Drawer 1857. |
| Oklahoma, Holdenville, 74848 | Gerhardt H. W. Schuster (o) (Franklin 9–3840) | P.O. Box 789; 5 Federal Building. |
| Oklahoma, McAlester, 74501 | A. M. Dinsmore (m) (Garden 3–5030) | 509 South 3rd Street. |
| Oklahoma, Miami, 75354 | Andrew V. Bailey (m) (Kimball 2–9481) | 205 Federal Building; P.O. Box 509. |
| Oklahoma, Oklahoma City, 73102 | Charley W. Nease (o) (Central 6–2311) | Room 4321 Federal, Court House and Office Building, 220 NW 4th Street. |
| Oklahoma, Tulsa, 74103 | Edward L. Johnson (c) and N. Orvis Frederick (o) (Luther 4–7161) | 521 Wright Building, 115 West 3rd Street. |
| Oregon, Portland, 97208 | Loyd L. Young (w) (Belmont 4–3351 x 577) | P.O. Box 3087; 411 Old Post Office Building. |
| Texas, Kilgore, 75662 | Warren W. Mankin (b) (5564) | P.O. Box 1230; Rader Building, 901–903 Broadway Building. |
| Texas, Midland, 79701 | Everett H. Patterson (b) (Mutual 4–6741) | P.O. Box 1830; 805 Petroleum Life Building, Texas and Colorado Streets. |
| Texas, Victoria, 77901 | John I. Watson (b) (Hillcrest 5–1841) | P.O. Box 2550; 228 Federal Building, Main and Church Streets. |
| Utah, Salt Lake City, 84111 | Ernest Blessing (m), Willard C. Gere (c), and Donald F. Russell (o), (Davis 8–2911 x 430, 429, 433) | 420 Empire Building, 231 East 4th South. |
| Washington, Tacoma, 48402 | Gordon C. Giles (w) (Market 7–1271) | Rm. 244 Federal Building; P.O. Box 1152. |
| Wyoming, Casper, 82601 | J. R. Schwabrow (o) and Donald M. Van Sickle (c), (23–7–2561) | 305 Federal Building, P.O. Box 400. |
| Wyoming, Newcastle, 82701 | Glenn E. Worden (o) (74–6–4554) | 611 South Summit Street; P.O. Box 231. |
| Wyoming, Rock Springs, 82901 | John Duletsky (o), (362–6422), and Arne A. Mattila (m), (362–7350) | 201 First Security Building, 502 S. Front Street; P.O. Box 1170. |
| Wyoming, Thermopolis, 82443 | Charles P. Clifford (o) (864–3477) | 202 Federal Building; P.O. Box 590. |

## GEOLOGIC DIVISION

| *Location* | *Geologist in charge and telephone number* | *Address* |
|---|---|---|
| Alaska, College, 99735 | Robert M. Chapman (3263) | P.O. Box 4004; Brooks Memorial Building. |
| California, Los Angeles, 90000 | John T. McGill (GRanite 3–0971, ext. 9881) | Geology Building, University of California. |
| Hawaii, Hawaii National Park, 96718 | James G. Moore | Hawaiian Volcano Observatory. |
| Hawaii, Honolulu, 96800 | Charles G. Johnson | District Building 96, Fort Armstrong. |
| Kansas, Lawrence, 66044 | Windsor L. Adkison (VIking 3–2700) | c/o State Geological Survey, Lindley Hall, University of Kansas. |
| Kentucky, Lexington, 40500 | Paul W. Richards (4–2473) | 496 Southland Drive. |
| Maryland, Beltsville, 20705 | Louis Pavlides (GRanite 4–4800, ext. 468) | U.S. Geological Survey Building, Department of Agriculture Research Center. |
| Massachusetts, Boston, 02100 | Lincoln R. Page (KEnmore 6–1444) | 270 Dartmouth Street, Room 1. |
| New Mexico, Albuquerque, 87100 | Charles B. Read (CHapel 7–0311, ext. 483) | P.O. Box 4083, Station A; Geology Building, University of New Mexico. |
| Ohio, Columbus, 43200 | James M. Schopf (AXminister 4–1810) | Orton Hall, Ohio State University, 155 South Oval Drive. |
| Pennsylvania, Mt. Carmel, 17851 | Jacques F. Robertson (339–4390) | P.O. Box 366; 56 West 2d Street. |
| Puerto Rico, Roosevelt, 00900 | Watson H. Monroe (San Juan 6–5340) | P.O. Box 803. |
| Tennessee, Knoxville, 37900 | Robert A. Laurence (2–7787) | 11 Post Office Building. |
| Utah, Salt Lake City, 84100 | Lowell S. Hilpert (DAvis 8–2911) | 231 East 4th Street. |
| Washington, Spokane, 99200 | Albert E. Weissenborn (TEmple 8–2084) | South 157 Howard Street. |
| Wisconsin, Madison, 53700 | Carl E. Dutton (ALpine 5–3311, ext. 2128) | 222 Science Hall, University of Wisconsin. |
| Wyoming, Laramie, 82070 | J. David Love (FRanklin 5–4495) | Geology Hall, University of Wyoming. |

## TOPOGRAPHIC DIVISION

| *Location* | *Engineer in charge and telephone number* | *Address* |
|---|---|---|
| Arlington, Va., 22200 | Charles F. Fuechsel (Jackson 5–7550) | 1109 N. Highland Street. |
| Rolla, Mo., 65401 | Daniel Kennedy (Emerson 4–3680) | Post Office Box 133; 9th and Elm Streets. |
| Denver, Colo., 80200 | Roland H. Moore (Lakewood Belmont 3–3611, ext. 548) | Federal Center Building 25. |
| Menlo Park, Calif., 94025 | Roy F. Thurston (Palo Alto Davenport 5–6761, ext. 4311) | 345 Middlefield Road. |

## WATER RESOURCES DIVISION

### Area Offices

| *Location* | *Official in charge* and telephone number* | *Address* |
|---|---|---|
| Atlantic Coast Area Arlington, Va., 22200 | George E. Ferguson, Division Hydrologist, (737–1820) | George Washington Building, Arlington Towers, 1011 Arlington Boulevard. |
| Midcontinent Area St. Louis, Mo., 63100 | Harry D. Wilson, Jr., Division Hydrologist, (621–8100) | Room 1252 Federal Building, 1520 Market Street. |
| Rocky Mountain Area Denver, Colo., 80200 | Sherman K. Jackson, Division Hydrologist, (233–3611) | Building 25, Denver Federal Center. |
| Pacific Coast Area Menlo Park, Calif., 94025 | Warren W. Hastings, Division Hydrologist, (325–6761) | 345 Middlefield Road. |

*The small letters in parentheses following each official's name signifies his affiliation in the Water Resources Division, as follows: g—Ground Water Branch; q—Quality of Water Branch; s—Surface Water Branch; w—Water Resources Division.

## District Offices

| *Location* | *Official in charge and telephone number* | *Address* |
|---|---|---|
| Alabama, University, 35486 | William J. Powell (g) and Lamar E. Carroon (s), (752–8104) | P.O. Box V; Oil and Gas Board Building, University of Alabama. |
| Alaska, Anchorage, 99500 | Melvin V. Marcher (g), (Broadway 2–8333) | Room 29, Federal Building. |
| Alaska, Juneau, 99801 | Ralph E. Marsh (s), (586–2815) | P.O. Box 2659; Room 203, Simpson Building, 222 Seward Street. |
| Alaska, Palmer, 99645 | Robert G. Schupp (q), (Pioneer 5–3450) | P.O. Box 36; Wright Building. |
| Arizona, Tucson, 85700 | Horace M. Babcock (g) and Douglas D. Lewis (s), (623–7731, ext. 291 and 294) | P.O. Box 4070; Geology Building, University of Arizona Campus. |
| Arkansas, Little Rock, 72200 | Richard T. Sniegocki (g), (372–4361, ext. 270) | Room 2307, Federal Building. |
| | John H. Hubble (q), (372–4361, ext. 219) | Room 2007, Federal Building. |
| | Ivan D. Yost(s), (372–4361, ext. 706) | Room 2301, Federal Building. |
| California, Menlo Park, 94025 | Walter Hofmann (s), (325–6761) | 345 Middlefield Road. |
| California, Sacramento, 95800 | Fred Kunkel (g), (449–2563) and Eugene Brown (q), (449–3174) | Rooms 8024 and 8042, Federal Building, 650 Capitol Avenue. |
| Colorado, Denver, 80200 | John W. Odell (s), (233–3611, ext. 6444) and Leonard A. Wood (g), (233–3611, ext. 546) | Denver Federal Center, Building 25. |
| Connecticut, Hartford, 06100 | John Horton (s), (527–3281, ext. 257) | P.O. Box 715; Room 203, Federal Building. |
| Connecticut, Middletown, 06457 | John A. Baker (g), (346–6986) | Room 204, Post Office Building. |
| Delaware, Dover, 19901 | Philip P. Fannebecker (s), (Redfield 4–2506) | P.O. Box 707; 604 Fairview Avenue. |
| Florida, Ocala, 32670 | Kenneth A. MacKichan (q) and Archibald O. Patterson (s) (622–6513) | Room 244, Federal Building. |
| Florida, Tallahassee, 32300 | Clyde S. Conover (g), (224–1202, 224–1203) | P.O. Box 2315, Gunter Building (Corner of Tennessee and Woodward Streets). |
| Georgia, Atlanta, 30300 | Harlan B. Counts (g), (688–5996) | Room 416, 19 Hunter Street, Southwest. |
| | Albert N. Cameron (s), (876–3311, ext. 5218) | Room 164, Peachtree Seventh Building. |
| Hawaii, Honolulu, 96800 | Dan A. Davis (g), (58–831, ext. 260) | Room 332, First Insurance Building, 1100 Ward Avenue. |
| | Mearle M. Miller (s), (58–831, ext. 251) | Room 330, First Insurance Building, 1100 Ward Avenue. |
| Idaho, Boise, 83700 | Wayne I. Travis (s), (344–4031) | Room 215, 914 Jefferson Street. |
| | Herbert A. Waite (g), (342–5441) | Room 205, 914 Jefferson Street. |
| Illinois, Champaign, 61820 | William D. Mitchell (s), (356–5221) | 605 South Neil Street. |
| Indiana, Indianapolis, 46200 | Malcolm D. Hale (s), (634–8734) and Claude M. Roberts (g), (634–9757) | Room 407, 611 North Park Avenue. |
| Iowa, Iowa City, 52240 | Vernal R. Bennion (s), (337–9345) | 508 Hydraulic Laboratory. |
| | Walter L. Steinhilber (g), (338–1173) | Geology Annex, State University of Iowa. |
| Kansas, Lawrence, 66044 | Robert J. Dingman (g), (843–2700, ext. 559) | c/o University of Kansas. |
| Kansas, Topeka, 66600 | Edward J. Kennedy (s), (233–0521) | P.O. Box 856; Room 403, Federal Building. |
| Kentucky, Louisville, 40200 | Robert V. Cushman (g) and Floyd F. Schrader (s), (584–1361, ext. 8235 and 8236) | Room 310, Center Building, 522 West Jefferson Street. |
| Louisiana, Baton Rouge, 70800 | Fay N. Hansen (s), (924–4215) | Room 215, Prudential Building, 6554 Florida Boulevard. |
| | Stanley F. Kapustka (q), (824–4215) | Room 201, Prudential Building, 6554 Florida Boulevard. |
| | Rex R. Meyer (g), (343–2873) | P.O. Box 8516; University Station, Room 43, Atkinson Hall, Louisiana State University. |
| Maine, Augusta, 04300 | Gordon S. Hayes (s) and Glenn C. Prescott (g), (623–4511, ext. 250) | Vickery Hill Building, Court Street. |
| Maryland, Baltimore, 21200 | Edmond G. Otton (g) (235–0771) | Room 103, Latrobe Hall, The Johns Hopkins University. |
| Maryland, College Park, 20740 | William E. Forrest (s), (927–6348) | P.O. Box 37; Room 106, Engineering Classroom Building, University of Maryland. |

| *Location* | *Official in charge and telephone number* | *Address* |
|---|---|---|
| Maryland, Rockville, 20850 | John W. Wark (q), (762–2885) | Room 3, Abbey Building, 3 North Perry Street. |
| Massachusetts, Boston, 02100 | Richard G. Peterson (g), 223–2822) | Room 206, 211 Congress Street. |
| | Charles E. Knox (s), (223–2824) | Room 205, 211 Congress Street. |
| Michigan, Lansing, 48900 | Arlington D. Ash (s), (489–2431) and Gerth E. Hendrickson (g), (489–7913) | Room 407, Capitol Savings and Loan Building. |
| Minnesota, St. Paul, 55100 | David B. Anderson (s), (222–8011, ext. 265) | Room 1610, New Post Office Building. |
| | Richmond H. Brown (g), (222–8011, ext. 260) | Room 1002, New Post Office Building. |
| Mississippi, Jackson, 39200 | Joe W. Lang (g), (354–3881, ext. 328) and William H. Robinson (s), (354–3881, ext. 326) | P.O. Box 2052: Room 300, U.S. Post Office Building. |
| Missouri, Rolla, 65401 | Anthony Homyk, Jr. (s), (364–1599) | P.O. Box 138; 900 Pine Street. |
| Montana, Billings, 59100 | Charles W. Lane (g), (259–2412) | P.O. Box 1818; Bell Building, 2 South 7th Street West. |
| Montana, Helena, 59600 | Frank Stermitz (s), (442–4890) | P.O. Box 1696; Room 409, Federal Building. |
| Nebraska, Lincoln, 68500 | Don M. Culbertson (q), Charles K. Keech (g), and Floyd F. Lefever (s), (435–3273, ext. 346, 323, and 328) | Room 125, Nebraska Hall, 901 North 17th Street. |
| Nevada, Carson City, 89700 | George F. Worts, Jr. (w), (472–1388) | P.O. Box B; 222 E. Washington Street. |
| New Jersey, Trenton, 08600 | John E. McCall (s), (394–5301, ext. 214) | P.O. Box 967; Room 433, Federal Building. |
| | Allen Sinnott (g), (394–5301, ext. 213) | P.O. Box 1238; Room 432, Federal Building. |
| New Mexico, Albuquerque, 87100 | Samuel W. West (g) and Jay M. Stow (q), (247–0311, ext. 2248 and 2249) | P.O. Box 4217; Geology Building, University of New Mexico. |
| New Mexico, Santa Fe, 87500 | Wilbur L. Heckler (s), (982–1921) | P.O. Box 277; 227 East Palace Avenue. |
| New York, Albany, 12200 | Ralph C. Heath (g), Donald F. Dougherty (s), Felix H. Pauszek (q), (463–5581) | P.O. Box 948; Rooms 342, 343, 348, Federal Building. |
| North Carolina, Raleigh, 27600 | Granville A. Billingsley (q), Granville G. Wyrick (g), (828–4345); Edward B. Rice (s), (834–6427) | P.O. Box 2857; 4th Floor, Federal Building. |
| North Dakota, Bismarck, 58500 | Harlan M. Erskine (s), (223–3525) | P.O. Box 750; Room 7, 202½ 3d Street. |
| North Dakota, Grand Forks, 58200 | Delbert W. Brown (g), (774–7221) | Box 8213 University Station. |
| Ohio, Columbus, 43200 | John J. Molloy (s), (221–6411, ext. 113) | 1509 Hess Street. |
| | George W. Whetstone (q), (221–6411, ext. 118) | 2822 East Main Street. |
| | Stanley E. Norris (g), (221–6411, ext. 281) | Room 554, U.S. Post Office Building, 85 Marconi Boulevard. |
| Oklahoma, Oklahoma City, 73100 | Alvin R. Leonard (g), (236–2311, ext. 412) | Room 4011, Federal Building, 200 Northwest 4th Street. |
| | Richard P. Orth (q), (677–5022) | P.O. Box 4355; 2800 South Eastern. |
| | Alexander A. Fischback, Jr. (s), (236–2311, ext. 257) | Room 4301, Federal Building, 200 Northwest 4th Street. |
| Oregon, Portland, 97200 | Roy B. Sanderson (s), Bruce L. Foxworthy (g), and Leslie B. Laird (q), (226–3361, ext. 239, 236, and 241) | P.O. Box 3418; Old Post Office Building, 511 NW Broadway. |
| Pennsylvania, Harrisburg, 17100 | Joseph E. Barcley (g), (238–4925) | 100 North Cameron Street. |
| | Robert E. Steacy (s), (238–5151, ext. 2724) | 1224 Mulberry Street. |
| Pennsylvania, Philadelphia, 19100 | Norman H. Beamer (q), (627–6000, ext. 274) | Room 1302, U.S. Custom House, 2d and Chestnut Streets. |
| Puerto Rico, San Juan, 00900 | Dean B. Bogart (w), (723–3989) | 1209 Fernandez Juncos Avenue, Santurce. |
| Rhode Island, Providence, 02900 | William B. Allen (g), (331–9312) | Room 401–2, Federal Building, U.S. Post Office. |
| South Carolina, Columbia, 29200 | Albert E. Johnson (s), (252–2449) | Room 121, Veterans Administration Regional Office Building, 1801 Assembly Street. |
| South Carolina, Columbia, 29200 | George E. Siple (g), (253–7478) | P.O. Box 5314; 627 Bull Street. |
| South Dakota, Huron, 57350 | John E. Powell (g), (352–8584) | P.O. Box 1412; Room 231, Federal Building. |
| South Dakota, Pierre, 57501 | John E. Wagar (s), (224–7856) | P.O. Box 216; Room 207, Federal Building. |
| Tennessee, Chattanooga, 37400 | Joseph S. Cragwall, Jr. (w), (226–2725) | Room 823, Edney Building. |

| *Location* | *Official in charge and telephone number* | *Address* |
|---|---|---|
| Texas, Austin, 78700 | Charles H. Hembree (q), Allen G. Winslow (g), and Trigg Twichell (s), (476–6411) | Vaughn Building, 807 Brazos Street. |
| Utah, Salt Lake City, 84100 | Russell H. Langford (q), (328–2911, ext. 596) | Room 305, Empire Building, 231 East 4th South. |
| | Ted Arnow (g), (328–2911, ext. 434) | Room 125, Empire Building, 231 East 4th South. |
| | Milton T. Wilson (s), (328–2911, ext. 435) | Room 130, Empire Building, 231 East 4th South. |
| Virginia, Charlottesville, 22900 | James W. Gambrell (s), (293–2127) | P.O. Box 3327; University Station, Natural Resources Building, McCormick Road. |
| Washington, Tacoma, 98400 | Arthur A. Garrett (g), (474–4261) | 3020 South 38th Street. |
| | Fred M. Veatch (s), (383–1491) | Room 207, Federal Building. |
| West Virginia, Charleston, 25300 | William C. Griffin (s), (343–6181, ext. 311) | 3303 New Federal Office Building, 500 Quarrier Street East. |
| West Virginia, Morgantown, 26500 | Gerald Meyer (g), (542–8103) | University of West Virginia, 405 Mineral Industries Building. |
| Wisconsin, Madison, 53700 | Charles R. Holt, Jr. (g), (255–3311, ext. 2329) | Room 175 Science Hall, University of Wisconsin. |
| | Kenneth B. Young (s), (256–4411, ext. 494) | Room 699, State Office Building. |
| Wyoming, Cheyenne, 82000 | Ellis D. Gordon (g) and Leon A. Wiard (s), (634–2731, ext. 37 and 23) | P.O. Box 177, Frangos Building, 2123 Carey Avenue. |
| Wyoming, Worland, 82401 | Thomas F. Hanley (q), (347–2181) | 1214 Big Horn Avenue. |

# OFFICES IN OTHER COUNTRIES

## GEOLOGIC DIVISION

| *Location* | *Geologist in Charge* | *Mailing Address* |
|---|---|---|
| Bolivia, La Paz | Charles M. Tschanz | U.S. Geological Survey, U.S. AID/Bolivia, c/o American Embassy, La Paz, Bolivia. |
| Brazil, Rio de Janeiro | Alfred J. Bodenlos | U.S. Geological Survey, U.S. AID/Rio, APO 676, New York, N.Y. |
| Chile, Santiago | Walter Danilchik | U.S. Geological Survey, c/o American Embassy, Santiago, Chile. |
| Dahomey, Cotonou | Jules A. MacKallor | U.S. Geological Survey, U.S. AID/Cotonou, U.S. Department of State, Washington, D.C., 20523. |
| Germany, Heidelberg | Jerald M. Goldberg | U.S. Geological Survey Team Representative (Europe), USAREUR Engineer Intelligence Center, APO 403, New York, N.Y. |
| Indonesia, Bandung | Robert F. Johnson | U.S. Geological Survey, U.S. AID/American Embassy, APO 156, San Francisco, Calif. |
| Pakistan, Quetta | John A. Reinemund | U.S. Geological Survey, U.S. AID/American Embassy, APO 271, New York, N.Y. |
| Philippines, Manila | Joseph F. Harrington | U.S. Geological Survey, c/o American Embassy, APO 928, San Francisco, Calif. |
| Thailand, Bangkok | Louis S. Gardner | U.S. Geological Survey/USOM, c/o American Embassy, APO 146, San Francisco, Calif. |
| Thailand, Bangkok | Charles T. Pierson | U.S. Geological Survey/UN, c/o American Embassy, APO 146, San Francisco, Calif. |

## WATER RESOURCES DIVISION

| *Location* | *Official in charge and telephone number* | *Mailing Address* |
|---|---|---|
| Afghanistan, Kabul | Robert H. Brigham | U.S. Geological Survey, U.S. AID/Kabul, U.S. Department of State, Washington, D.C., 20523. |
| Brazil, Recife | Stuart L. Schott (g) and Leonard J. Snell (s) | U.S. Geological Survey, U.S. AID/Brazil (Recife), APO 676, New York, N.Y. |
| Brazil, Rio de Janeiro | Dagfin J. Cederstrom | U.S. Geological Survey, U.S. AID/Brazil, APO 676, New York, N.Y. |

| | *Official in charge and telephone number* | *Mailing Address* |
|---|---|---|
| Iran, Tehran* | Alvin F. Jones | U.S. Geological Survey, Branch of Foreign Hydrology, Washington, D.C., 20242. |
| Libya, Tripoli | James R. Jones | U.S. Geological Survey, U.S. AID/Libya, APO 231, New York, N.Y. |
| Nepal, Katmandu | Daniel E. Havelka | U.S. Geological Survey, U.S. AID/N, APO 959, Box Kat, San Francisco, Calif. |
| Nigeria, Kaduna | David A. Phoenix | U.S. Geological Survey, U.S. AID/Lagos (Kaduna), U.S. Department of State, Washington, D.C., 20523. |
| Pakistan, Lahore | Maurice J. Mundorff | U.S. Geological Survey, U.S. AID/Pakistan, APO 271, New York, N.Y. |
| Sudan, Khartoum* | Harry G. Rodis | U.S. Geological Survey, Branch of Foreign Hydrology, Washington, D.C., 20242. |
| Tunisia, Tunis | Vinton C. Fishel | U.S. Geological Survey, c/o U.S. AID/Tunis, U.S. Dept. of State, Washington, D.C., 20523. |
| Turkey, Ankara | C. Richard Murray | U.S. Geological Survey, U.S. Economic Coordinator/ Ankara, APO 254, New York, N.Y. |
| United Arab Republic, Egypt, Cairo | Raymond W. Sundstrom | U.S. Geological Survey, U.S. AID/Cairo, U.S. Dept. of State, Washington, D.C., 20523. |

*Program terminated August 1963.

# INVESTIGATIONS IN PROGRESS IN THE GEOLOGIC, WATER RESOURCES, AND CONSERVATION DIVISIONS

Investigations in progress during fiscal year 1963 are listed below, together with the names and headquarters of the individuals in charge of each. Headquarters at main centers are indicated by (W) for Washington, D.C., (D) for Denver, Colo., and (M) for Menlo Park, Calif. Headquarters in other cities are indicated by name; see list of offices (p. A252) for addresses. Lowercase letter following the name of the project leader shows the division technical responsibility: c, Conservation Division; w, Water Resources Division (g, Ground Water Branch; s, Surface Water Branch; q, Quality of Water Branch; h, General Hydrology Branch); no letter, Geologic Division.

The projects are classified by principal topic. Most geologic-mapping projects involve special studies of stratigraphy, petrology, geologic structure, or mineral deposits, but are listed only under Geologic Mapping unless a special topic or commodity are the primary justification for the project. A reader interested in investigations of volcanology, for example, should look under the heading Geologic Mapping for projects in areas of volcanic rocks, as well as under the heading Volcanology. Likewise, most water-resources investigations involve special studies of several aspects of hydrology and geology, but are listed only under Water Resources unless the special topic—such as floods or sedimentation—is the primary justification for the project.

Areal geologic mapping is subdivided into mapping at scales smaller than 1 inch to 1 mile (for example, 1:250,000), and mapping at scales of 1 inch to 1 mile, or larger (1:62,500; 1:24,000).

Analytical chemistry:
- Analytical methods—water chemistry (M. W. Skougstad, q, D)
- Analytical services and research (I. May, W; L. F. Rader, Jr., D; R. E. Stevens, M)
- Determination of microquantities of $NH_4^{+1}$ in water (G. Stratton, q, Columbus, Ohio)
- Organic geochemistry and infrared analysis (I. A. Breger, W)
- Organic substances in water (W. L. Lamar, q, M)
- Rock and mineral chemical analysis (J. J. Fahey, W)
- Rock chemical analysis, general (L. C. Peck, D)
- Rock chemical analysis, rapid (L. Shapiro, W)
- Trace analysis methods, research (F. N. Ward, D)
- Trace analysis service (F. N. Ward, D)
- *See also* Spectroscopy.

Artificial recharge:
- Artificial recharge at Kalamazoo, Mich. (J. E. Reed, g, Lansing)
- Artificial recharge of aquifers (R. T. Sniegocki, g, Little Rock, Ark.)
- Artificial recharge of basalt aquifers, Salem Heights, Oreg. (B. L. Foxworthy, g, Portland)
- Artificial recharge of basalt aquifers, The Dalles, Oreg. (B. L. Foxworthy, g, Portland)
- Artificial recharge of the Grand Prairie region, Arkansas—ground water (R. T. Sniegocki, g, Little Rock)
- Experimental recharge basin—surface water (R. M. Sawyer, s, Albany, N.Y.)
- Recharge studies on the High Plains, N. Mex. (J. S. Havens, g, Albuquerque)
- Water application and use on a range water spreader, northeast Montana (F. A. Branson, h, D)

Asbestos:
- Arizona, McFadden Peak and Blue House quadrangles (A. F. Shride, D)
- Vermont, north-central (W. M. Cady, D)

Barite:
- Arkansas (D. A. Brobst, D)

Base metals:
- Colorado:
  - Tenmile Range and Kokomo mining district (M. H. Bergendahl, D)
  - Wet Mountains (M. R. Brock, D)
- Montana, Philipsburg area (W. C. Prinz, W)
- Nevada, Antler Peak quadrangle (R. J. Roberts, M)
- Utah, San Francisco Mountains (D. M. Lemmon, M)
- *See also base-metal names.*

Bauxite:
- Aeromagnetic prospecting (A. Jespersen, W)
- Hawaii, Kauai (S. H. Patterson, W)
- Southeastern United States (E. F. Overstreet, W)

Beryllium:
- Alaska, Lost River mining district (C. L. Sainsbury, D)
- Beryllium in volcanic and associated rocks, western United States (D. R. Shawe, D)
- Colorado:
  - Lake George district (C. C. Hawley, D)
  - Mt. Antero (W. N. Sharp, D)
- Nevada, Mt. Wheeler mine area (D. E. Lee, M)
- Utah, Thomas and Dugway Ranges (M. H. Staatz, D)

Bibliographies and abstracts:
- Bibliography of North American geology (M. Cooper, W)
- Geochemical exploration abstracts (E. L. Markward, D)
- Geophysical abstracts (J. W. Clarke, W)
- Index of literature on Alaskan geology (E. H. Cobb, M)
- Vanadium, geology and resources, bibliography (J. P. Ohl, D)

Construction and terrain problems—Continued
- Mudflow studies (D. R. Crandell, D)
- Nuclear-explosion effects (W. E. Hale, Albuquerque, N.M.)
- Alaska:
  - Mt. Hayes D–3 and D–4 quadrangles (T. L. Péwé, College)
  - Northeastern Alaska coastal plain and foothills (C. R. Lewis, W)
  - Origin and stratigraphy of ground ice in central Alaska T. L. Péwé, College)
  - Project CHARIOT (harbor construction) (G. D. Eberlein, M)
  - Surficial and engineering geology:
    - Anchorage-Matanuska Glacier area (T. N. V. Karlstrom, W)
    - Bristol Bay area (E. H. Muller, Ithaca, N.Y.)
    - Construction-materials sources (T. L. Péwé, College)
    - Copper River Basin northeastern, (O. J. Ferrians, Jr., W)
    - Copper River Basin, southeastern, (D. R. Nichols, W)
    - Copper River Basin, southwestern, (J. R. Williams, W)
    - Eastern Denali Highway (D. R. Nichols, W)
    - Johnson River district (H. L. Foster, W)
    - Kenai lowland (T. N. V. Karlstrom, W)
    - Kobuk River valley (A. T. Fernald, W)
    - Lower Chitina Valley (L. A. Yehle, W)
    - Mt. Chamberlain area (C. R. Lewis, W)
    - Seward-Portage Railroad (T. N. V. Karlstrom, W)
    - Slana-Tok area (H. R. Schmoll, W)
    - Steese Highway area (W. E. Davies, W)
    - Taylor Highway area (H. L. Foster, W)
    - Upper Tanana River (A. T. Fernald, W)
    - Valdez-Tiekel belt (H. W. Coulter, W)
    - Yukon-Koyukuk lowland, (F. R. Weber, College)
- California:
  - Los Angeles area (J. T. McGill, Los Angeles)
  - Morrison quadrangle (J. H. Smith, Corbin, Ky.)
  - Oakland East quadrangle (D. H. Radbruch, M)
  - Palo Alto quadrangle (E. H. Pampeyan, M)
  - Point Dume quadrangle (R. H. Campbell, M)
  - San Francisco North quadrangle (J. Schlocker, M)
  - San Francisco South quadrangle (M. G. Bonilla, M)
  - San Mateo quadrangle (G. O. Gates, M)
- Colorado:
  - Air Force Academy (D. J. Varnes, D)
  - Black Canyon of the Gunnison River (W. R. Hansen, D)
  - Denver metropolitan area (R. M. Lindvall, D)
  - Golden quadrangle (R. Van Horn, D)
  - Morrison quadrangle (J. H. Smith, Corbin, Ky.)
  - Pueblo and vicinity (G. R. Scott, D)
  - Roberts Tunnel (C. S. Robinson, D)
  - Straight Creek tunnel (C. S. Robinson, D)
  - Upper Green valley (W. R. Hansen, D)
- District of Columbia, Washington metropolitan area (H. W. Coulter and C. F. Withington, W)
- Greenland, terrain studies (W. E. Davies, W)
- Iowa, Omaha–Council Bluffs and vicinity (R. D. Miller, D)
- Maryland, Washington, D.C., metropolitan area (H. W. Coulter and C. F. Withington, W)

Construction and terrain problems—Continued
- Massachusetts:
  - Application of geology and seismology to public-works planning (C. R. Tuttle and R. N. Oldale, Boston)
  - Boston and vicinity (C. A. Kaye, Boston, Mass.)
  - Sea-cliff erosion studies (C. A. Kaye)
- Montana:
  - Fort Peck area (H. D. Varnes, D)
  - Great Falls area (R. W. Lemke, D)
  - Wolf Point area (R. B. Colton, W)
- Nebraska:
  - Franklin, Webster, and Nuckolls Counties (R. D. Miller, D)
  - Omaha–Council Bluffs and vicinity (R. D. Miller, D)
  - Valley County (R. D. Miller, D)
- Nevada Test Site, site studies (R. E. Davis, D)
- New Mexico, Nash Draw quadrangle (L. M. Gard, D)
- Oregon, Portland industrial area (D. E. Trimble, D)
- South Dakota:
  - Fort Randall Reservoir area (H. D. Varnes, D)
  - Rapid City area (E. Dobrovolny, D)
- Tennessee, Knoxville and vicinity (J. M. Cattermole, Columbia, Ky.)
- Utah:
  - Coal-mine bumps (F. W. Osterwald, D)
  - Oak City area (D. J. Varnes, D)
  - Salt Lake City and vicinity (R. Van Horn, D)
  - Upper Green River valley (W. R. Hansen, D)
- Virginia:
  - Herndon quadrangle (R. E. Eggleton, M)
  - Washington, D.C., metropolitan area (H. W. Coulter and C. F. Withington, W)
- Washington:
  - Portland industrial area (D. E. Trimble, D)
  - Puget Sound (D. R. Crandell, D)
  - Seattle and vicinity (D. R. Mullineaux, D)

Copper:
- Massive sulfide deposits (A. R. Kinkel, Jr., W)
- Sandstone copper deposits, southwest United States (C. B. Read, Albuquerque, N. Mex.)
- Alaska, southern Brooks Range (W. P. Brosgé, M)
- Arizona:
  - Benson and Mammoth quadrangles (S. C. Creasey, M)
  - Globe–Miami area (D. W. Peterson, M)
  - Klondyke quadrangle (F. S. Simons, D)
  - Little Dragoons area (J. R. Cooper, D)
  - Lochiel and Nogales quadrangles (F. S. Simons, D)
  - Twin Buttes area (J. R. Cooper, D)
- Colorado, Lisbon Valley area (G. W. Weir, Berea, Ky.)
- Michigan, Michigan copper district (W. S. White, W)
- Nevada, Ely district (A. L. Brokaw, D)
- New Mexico, Silver City region (W. R. Jones, D)
- North Carolina, Swain County district (G. H. Espenshade, W)
- Tennessee, Ducktown district and adjacent areas (R. M. Hernon, D)
- Utah:
  - Bingham Canyon district (R. J. Roberts, M)
  - Deer Flat area, White Canyon district (T. L. Finnell, D)
  - Lisbon Valley area (G. W. Weir, Berea, Ky.)
  - White Canyon area (R. E. Thaden, Columbia, Ky.)

Crustal studies. *See* Geophysics, regional.

Geochemical distribution of the elements—Continued
- Areal studies—Continued
  - Georgia, biogeochemical reconnaissance (H. T. Shacklette, D)
  - Montana, Boulder batholith, petrochemistry (R. I. Tilling, W)
  - Nevada, Mt. Wheeler mine area, beryllium distribution (D. E. Lee, M)
  - Wisconsin, Driftless Area, geochemical survey (H. T. Shacklette, D)

Geochemical prospecting methods:
- Botanical exploration and research (H. L. Cannon, D)
- Dispersion pattern of minor elements related to igneous intrusions (W. R. Griffitts, D)
- Geochemical exploration abstracts (E. L. Markward, D)
- Instrument-development laboratory (W. W. Vaughn, D)
- Mineral exploration methods (G. B. Gott, D)
- Mobile spectrographic laboratory (F. N. Ward, D)
- Plant analysis laboratory (F. N. Ward, D)
- Areal studies:
  - Alaska, geochemical prospecting techniques (R. M. Chapman, College)
  - Arizona and New Mexico, geochemical halos of mineral deposits (L. C. Huff, Manila, P.I.)
  - Maine:
    - Geochemical mapping (E. V. Post, D)
    - The Forks quadrangle (F. C. Canney and E. V. Post, D)
  - Utah and Nevada, geochemical halos of mineral deposits, (R. L. Erickson, D)

Geochemistry, experimental:
- Alkali and alkaline-earth salt systems (E. Zen, W)
- Environment of ore deposition (P. Toulmin III, W)
- Evaporite-mineral equilibria (E. Zen, W)
- Fluid inclusions in minerals (E. W. Roedder, W)
- Geologic thermometry (E. H. Roseboom, Jr., W)
- Hydrothermal silicate systems (P. Toulmin III, W)
- Hydrothermal solubility (G. W. Morey, W)
- Metallic sulfides and sulfosalt systems (P. Toulmin III, W)
- Organic geochemistry and infrared analysis (I. A. Breger, W)
- Rock weathering and alteration (J. J. Hemley, M)
- Solubilities of minerals in aqueous fluids (P. Toulmin III, W)
- Solution-mineral equilibria (C. L. Christ, W)
- Thermodynamic properties of minerals (E. H. Roseboom, Jr., W)

Geochemistry and petrology, field studies:
- Cave deposits, stratigraphy and mineralogy (W. E. Davies, W)
- Clay studies, Colorado Plateau (L. G. Schultz, D)
- Geochemical sampling and statistical analysis of data (A. T. Miesch, D)
- Geochemistry of minor elements (G. Phair, W)
- Green River Formation, mineralogy and geochemistry (C. Milton, W)
- Humates, geology and geochemistry (V. E. Swanson, D)
- Igneous rocks of Southeastern United States (C. Milton, W)
- Jasperoids (T. G. Lovering, D)
- Metamorphic rocks and ore deposits (R. G. Coleman, M)
- Pacific Coast basalts, geochemistry (K. J. Murata, M)
- Pierre Shale, chemical and physical properties, Montana, North Dakota, South Dakota, Wyoming, and Nebraska (H. A. Tourtelot, D)

Geochemistry and petrology, field studies—Continued
- Rare-earth elements, resources and geochemistry (J. W. Adams, D)
- Sedimentary-petrology laboratory (H. A. Tourtelot, D)
- Selenium, resources and geochemistry (D. F. Davidson, D)
- Taconic sequence, Massachusetts, New York, and Connecticut (E. Zen, W)
- Thermal waters, origin and characteristics (D. E. White, M)
- Alaska, petrology and volcanism, Katmai National Monument (G. H. Curtis, M)
- California:
  - Burney area (G. A. Macdonald, Honolulu, Hawaii)
  - Franciscan Formation, glaucophane schist (R. G. Coleman, M)
  - Sierra Nevada batholith, geochemistry study (F. Dodge, M)
- Colorado:
  - Colorado Front Range, Boulder Creek batholith (G. Phair, W)
  - Colorado Front Range, Laramide intrusives (G. Phair, W)
  - Minturn quadrangle (T. S. Lovering, D)
  - Mount Princeton area, distribution of elements (P. Toulmin III, W)
  - Wet Mountains, wallrock alteration (G. Phair, W)
- Hawaii, Hawaiian volcanology (J. G. Moore, Hawaii National Park, Hawaii)
- Idaho, central Snake River plain, volcanic petrology (H. A. Powers, D)
- Montana:
  - Bearpaw Mountains, petrology (W. T. Pecora, W)
  - Boulder batholith, petrochemistry (R. I. Tilling, W)
  - Stillwater Complex, petrology and chromite resources (E. D. Jackson, W)
  - Wolf Creek area, petrology (R. G. Schmidt, W)
- New Mexico:
  - Grants area, mineralogy of uranium-bearing rocks (A. D. Weeks, W)
  - Valles Mountains (R. L. Smith, W)
- New York, Gouverneur area, metamorphism and origin of mineral deposits (A. E. J. Engel, La Jolla, Calif.)
- South Carolina, igneous and metamorphic rocks of the piedmont (W. C. Overstreet, W)
- Texas, Karnes and Duval Counties, mineralogy of uranium-bearing rocks (A. D. Weeks, W)
- Wisconsin, geochemical survey of the Driftless Area (H. T. Shacklette, D)
- Wyoming:
  - Green River Formation, geology and paleolimnology (W. H. Bradley, W)
  - Yellowstone Park, thermal waters (G. W. Morey, W)

Geochemistry, water:
- Chemistry of atmospheric precipitation (A. W. Gambell, Jr., q, W)
- Chloride concentration in precipitation from extra-tropical storms, New Jersey (E. C. Rhodehamel, g, Trenton)
- Composition of supercritical fluids in the system $K_2O$–$Al_2O_3$–$SiO_2$–$H_2O$ (C. J. Spengler, q, W)
- Effect of physical factors on exchange reactions occurring during water flow through porous media (Jacob Rubin, h, M)

Geochemistry, water—Continued
- Fluoride in ground water, Horry County area, South Carolina (N. Baker, q, W)
- Fluoride in ground water, northwestern Florida (L. Toler, q, Ocala)
- Geochemical controls of water quality (Ivan Barnes, q, W)
- Geochemistry of ground water in the Englishtown Formation, New Jersey (P. R. Seaber, g, Trenton)
- Geochemistry of water in carbonate rocks (W. Back, g, W)
- Hydrosolic metals in natural water (J. D. Hem, q, D)
- Ion exchange in water chemistry (G. Stratton, q, Columbus, Ohio)
- Investigations of cesium in natural waters (H. C. Whitehead, q, M)
- Mineral constituents in ground water and their origin (J. H. Feth, g, M)
- Minor constitutents in the Belle Fourche River, South Dakota (L. R. Petri, q, Lincoln, Nebr.)
- Occurrence and distribution of minor elements in fresh and saline waters of California (W. D. Silvey, q, Sacramento)
- Occurrence and distribution of radioelements in water (R. C. Scott, q, D)
- Occurrence and distribution of the rare halogens (I. Barnes, q, W)
- Solute composition and minor element distribution in lacustrine closed basins (B. F. Jones, q. W)
- Solute-solid relations in lacustrine closed basins of the alkali-carbonate type (B. F. Jones, q, W)
- Spatial distribution of chemical constituents in ground water, Eastern United States (W. Back, g, W)

Geochronology:
- Carbon-14 method (M. Rubin, W)
- Geologic time scale (S. S. Goldich, W)
- K/A and Rb/Sr methods (H. H. Thomas and C. E. Hedge, W, and R. Kistler, M)
- Lead-alpha method (T. W. Stern, W)
- Lead-uranium method (P. Banks, W)
- Radioactive-disequilibrium studies (J. N. Roshol, D)
- Southeastern Alaska (G. D. Eberlein and M. A. Lanphere, M)
- *See also* Isotope and nuclear studies.

Geologic mapping:
- Map scale smaller than 1 inch to 1 mile:
  - Colorado Plateau, geologic maps (2-degree sheets) (D. G. Wyant, D)
  - Colorado Plateau, photogeologic mapping (A. B. Olson, W)
  - Alaska:
    - Bristol Bay area, surficial geology (E. H. Muller, Ithaca, N.Y.)
    - Buckland and Huslia Rivers area, west-central Alaska (W. W. Patton, Jr., M)
    - Central and northern Alaska Cenozoic (D. M. Hopkins, M)
    - Charley River quadrangle (E. E. Brabb, M)
    - Compilation of geologic maps, 1:250,000 quadrangles (W. H. Condon, M)
    - Delong Mountains and Point Hope quadrangles (I. L. Tailleur, M)
    - Fairbanks quadrangle (F. R. Weber, College)
    - Geologic map of State (G. O. Gates, M)
    - Hughes-Shungnak area (W. W. Patton, Jr., M)
    - Iliamna quadrangle (R. L. Detterman, M)

Geologic mapping—Continued
- Map scale smaller than 1 inch to 1 mile—Continued
  - Alaska—Continued
    - Kenai lowland, surficial geology (T. N. V. Karlstrom, W)
    - Klukwan iron district (E. C. Robertson, W)
    - Kobuk River valley (A. T. Fernald, W)
    - Livengood quadrangle (B. Taber, M)
    - Lower Yukon-Koyukuk area (W. W. Patton, Jr., M)
    - Lower Yukon-Norton Sound region (J. M. Hoare, M)
    - Nelchina area (A. Grantz, M)
    - Northern Alaska petroleum investigations (G. Gryc, M)
    - Southeastern Alaska, regional geology and mineral resources (R. A. Loney, M)
    - Southern Brooks Range (W. P. Brosgé, M)
    - Yukon-Koyuku lowland, engineering geology (F. R. Weber, College)
  - Antarctica:
    - Eights and Walgreen Coasts, reconnaissance geology A. A. Drake, Jr., W)
    - Western Antarctica, reconnaissance geology (E. L. Boudette, W)
  - Colorado:
    - Colorado National Monument (S. W. Lohman, g, D)
    - Grand Junction 2-degree quadrangle (W. B. Cashion, D)
    - Oil-shale investigations (D. C. Duncan, W)
  - Idaho:
    - Central Snake River plain, volcanic petrology (H. A. Powers, D)
    - Mackay quadrangle (C. P. Ross, D)
    - South-central Idaho (C. P. Ross, D)
    - Spokane-Wallace region (A. B. Griggs, M)
  - Montana, Spokane-Wallace region (A. B. Griggs, M)
  - Nevada:
    - Clark County (C. R. Longwell, M)
    - Esmeralda County (J. P. Albers, M)
    - Eureka County (R. J. Roberts, M)
    - Humboldt County (C. R. Willden, D)
    - Lincoln County (C. M. Tschanz, La Paz, Bolivia)
    - Lyon, Douglas, and Ormsby Counties (J. G. Moore, Hilo, Hawaii)
    - Nevada Test Site, reconnaissance (F. N. Houser, D)
    - Nye County, northern part (F. J. Kleinhampl, M)
    - Nye County, southern part (H. R. Cornwall, M)
    - Pershing County (D. B. Tatlock, M)
  - New Mexico, geologic map (C. H. Dane, W)
  - Ohio, Glacial mapping (G. W. White and R. P. Goldthwait, g, Columbus)
  - Oregon, geologic map (G. W. Walker, M)
  - Utah, Grand Junction 2-degree quadrangle (W. B. Cashion, D)
  - Washington:
    - Grays Harbor basin, regional compilation (H. M. Beikman, M)
    - Spokane-Wallace region (A. B. Griggs, M)
- Map scale 1 inch to 1 mile, and larger:
  - Alabama:
    - Limestone County, Elkmont and Salem quadrangles (W. M. McMaster, g, Tuscaloosa)
    - Warrior quadrangle (W. C. Culbertson, D)

Geologic mapping—Continued
Map scale 1 inch to 1 mile, and larger—Continued
Alaska:
Aleutian Islands, eastern (R. E. Wilcox, D)
Aleutian Islands, western (R. E. Wilcox, D)
Aleutian Trench—Trinity Island (G. W. Moore, M)
Anchorage—Matanuska Glacier area, surficial geology (T. N. V. Karlstrom, W)
Beluga-Yentna area (F. F. Barnes, M)
Project CHARIOT (harbor construction) (G. D. Eberlein, M)
Copper River Basin, northeastern, surficial geology (O. J. Ferrians, Jr., W)
Copper River Basin, southeastern, surficial geology (D. R. Nichols, W)
Copper River Basin, southwestern, surficial geology (J. R. Williams, W)
Eastern Denali Highway, surficial geology (D. R. Nichols, W)
Gulf of Alaska Tertiary province (G. Plafker, M)
Heceta-Tuxekan area (G. D. Eberlein, M)
Iniskin-Tuxedni region (R. L. Detterman, M)
Johnson River district, surficial geology (H. L. Foster, W)
Katmai National Monument, petrology and volcanism (G. H. Curtis, M)
Lost River mining district (C. L. Sainsbury, D)
Lower Chitina Valley, surficial geology (L. A. Yehle, W)
Mt. Chamberlain area, surficial geology (C. R. Lewis, W)
Mt. Hayes D-3 and D-4 quadrangles (T. L. Péwé, College)
Mount Michelson area (E. G. Sable, Elizabethtown, Ky.)
Nenana coal investigations (C. Wahrhaftig, M)
Nome C-1 and D-1 quadrangles (C. L. Hummel, M)
Northeastern Alaska coastal plain and foothills (C. R. Lewis, W)
Seward-Portage Railroad, surficial geology (T. N. V. Karlstrom, W)
Slana-Tok area, surficial geology (H. R. Schmoll, W)
Steese Highway area, surficial geology (W. E. Davies, W)
Taylor Highway area, surficial geology (H. L. Foster, W)
Tofty placer district (D. M. Hopkins, M)
Upper Tanana River, surficial geology (A. T. Fernald, W)
Valdez-Tiekel belt, surficial geology (H. W. Coulter, W)
Windy-Curry area (R. Kachadoorian, M)
Antarctica:
Horlick Mountains (A. B. Ford, W)
Pensacola Mountains (A. B. Ford, W)
Wrangell Mountains, southern (E. M. Mackevett, Jr., M)
Arizona:
Bradshaw Mountains (C. A. Anderson, W)
Carrizo Mountains area (J. D. Strobell, D)
Christmas quadrangle (C. R. Willden, D)
Cibecue-Grasshopper area (T. L. Finnell, D)
Cochise County, southern part (P. T. Hayes, D)

Geologic mapping—Continued
Map scale 1 inch to 1 mile, and larger—Continued
Arizona—Continued
Elgin quadrangle (R. B. Raup, D)
Gila River basin, upper part (R. B. Morrison, D)
Globe-Miami area (D. W. Peterson, M)
Heber quadrangle (E. J. McKay, D)
Holy Joe Peak quadrangle (M. H. Krieger, M)
Klondyke quadrangle (F. S. Simons, D)
Little Dragoons area (J. R. Cooper, D)
Lochiel and Nogales quadrangles (F. S. Simons, D)
McFadden Peak and Blue House Mountain quadrangles (A. F. Shride, D)
Mammoth and Benson quadrangles (S. C. Creasey, M)
Mount Wrightson quadrangle (H. Drewes, D)
Navajo Reservation, fuels potential (R. B. O'Sullivan, D)
Prescott-Paulden area (M. H. Krieger, M)
Show Low quadrangle (E. J. McKay, D)
Twin Buttes area (J. R. Cooper, D)
Arkansas:
Arkansas Basin, coal investigations (B. R. Haley, D)
Ft. Smith district (T. A. Hendricks, D)
Magnet Cove, niobium investigations (L. V. Blade, Paducah, Ky.)
Malvern quadrangle (W. Danilchik, Santiago, Chile)
Northern Arkansas, oil and gas investigations (E. E. Glick, D)
California:
Ash Meadows quadrangle (C. S. Denny, W)
Beatty area (H. R. Cornwall, M)
Big Maria, Little Maria, and Riverside Mountains (W. B. Hamilton, D)
Bishop tungsten district (P. C. Bateman, M)
Blanco Mountain quadrangle (C. A. Nelson, Los Angeles)
Burney area (G. A. Macdonald, Honolulu, Hawaii)
Coast Range ultramafic rocks (E. H. Bailey, M)
Condrey Mountain quadrangle (P. E. Hotz, M)
Cuyama Valley area (J. G. Vedder, M)
Death Valley (C. B. Hunt, Baltimore, Md.)
Funeral Peak quadrangle (H. Drewes, D)
Furnace Creek area (J. F. McAllister, M)
Independence quadrangle (D. C. Ross, M)
Klamath Mountains, southern part (W. P. Irwin, M)
Los Angeles area (J. T. McGill, Los Angeles)
Los Angeles basin, eastern part (J. E. Schoellhamer, W)
Malibu Beach quadrangle (R. F. Yerkes, M)
Merced Peak quadrangle (D. L. Peck, Hawaii)
Mojave Desert, south-central (T. W. Dibblee, Jr., M)
Mojave Desert, western (T. W. Dibblee, Jr., M)
Mt. Diablo area (E. H. Pampeyan, M)
Mt. Pinchot quadrangle (J. G. Moore, Hawaii)
New York Butte quadrangle (W. C. Smith, M)
Oakland East quadrangle (D. H. Radbruch, M)
Palo Alto quadrangle (E. H. Pampeyan, M)
Panamint Butte quadrangle (W. E. Hall, W)
Point Dume quadrangle (R. H. Campbell, M)

Geologic mapping—Continued
- Map scale 1 inch to 1 mile, and larger—Continued
  - California—Continued
    - Sacramento Valley, northwest part (R. D. Brown, Jr., W)
    - Salinas Valley (D. L. Durham, M)
    - San Andreas fault (L. F. Noble, Valyermo)
    - San Francisco North quadrangle (J. Schlocker, M)
    - San Francisco South quadrangle (M. G. Bonilla, M)
    - San Mateo quadrangle (G. O. Gates, M)
    - San Nicolas Island (J. G. Vedder, M))
    - Searles Lake area (G. I. Smith, M)
    - Shuteye Peak area (N. K. Huber, M)
    - Sierra foothills mineral belt (L. D. Clark, M)
    - Sierra Nevada batholith (P. C. Bateman, M)
    - Sierra tungsten belt, eastern (N. K. Huber, M)
  - Colorado:
    - Air Force Academy (D. J. Varnes, D)
    - Animas River area (H. Barnes, D)
    - Anthracite NW and Snowmass SW quadrangles (D. L. Gaskill, c, D)
    - Baggs area (G. E. Prichard, D)
    - Berthoud Pass quadrangle (P. K. Theobald, D)
    - Black Canyon of the Gunnison River (W. R. Hansen, D)
    - Bottle Pass and Black Hawk quadrangles (R. B. Taylor, D)
    - Boulder quadrangle (C. T. Wrucke, D)
    - Bull Canyon district (C. H. Roach, D)
    - Cameron Mountain quadrangle (M. G. Dings, D)
    - Carbondale coal field (J. R. Donnell, D)
    - Cerro Summit quadrangle (R. G. Dickinson, c, D)
    - Creede district (T. A. Steven, D)
    - Denver metropolitan area (R. M. Lindvall, D)
    - Eldorado Springs quadrangle (J. D. Wells, W)
    - Elk Springs quadrangle (J. R. Dyni, c, D)
    - Empire quadrangle (W. A. Braddock, D)
    - Fort Lupton, Hudson, and Platteville quadrangles (P. E. Soister, c, D)
    - Front Range, Fort Collins area (W. A. Braddock, D)
    - Glenwood Springs quadrangle (N. W. Bass, D)
    - Golden quadrangle (R. Van Horn, D)
    - Grand-Battlement Mesa (J. R. Donnell, D)
    - Green River Valley, upper part (W. R. Hansen, D)
    - Holy Cross quadrangle (O. Tweto, D)
    - Hot Sulphur Springs and Kremmling quadrangles (G. A. Izett, c, D)
    - La Sal area (W. D. Carter, W)
    - Lafayette quadrangle (K. B. Ketner, D)
    - Lake George district (C. C. Hawley, D)
    - Lisbon Valley area (G. W. Weir, Berea, Ky.)
    - Maybell-Lay area (M. J. Bergin, W)
    - Montrose 1 SW, 1 SE, and 4 NE quadrangles (R. G. Dickinson, c, D)
    - Morrison quadrangle (J. H. Smith, Corbin, Ky.)
    - Mountain front area, east-central Front Range (D. M. Sheridan, D)
    - Mt. Antero (W. N. Sharp, D)
    - Mt. Harvard quadrangle (M. R. Brock, D)
    - North Park, eastern (D. M. Kinney, W)
    - North Park, western (W. J. Hail, D)

Geologic mapping—Continued
- Map scale 1 inch to 1 mile, and larger—Continued
  - Colorado—Continued
    - Poncha Springs and Bonanza quadrangles (R. E. Van Alstine, W)
    - Powderhorn area (J. C. Olson, D)
    - Pueblo and vicinity (G. R. Scott, D)
    - Ralston Buttes (D. M. Sheridan, D)
    - Rico-Animas area (A. L. Bush, D)
    - Rico district (E. T. McKnight, W)
    - San Juan mining area (R. G. Luedke, W)
    - San Juan Mountains, western (A. L. Bush, D)
    - Slick Rock district (D. R. Shawe, D)
    - South Platte River, upper part (G. R. Scott, D)
    - Squaw Pass, Evergreen, and Indian Hills quadrangles (D. M. Sheridan, D)
    - Straight Creek tunnel (C. S. Robinson, D)
    - Tenmile Range and Kokomo mining district (M. H. Bergendahl, D)
    - Thornburg area (J. R. Dyni, c, D)
    - Trinidad coal field (R. B. Johnson, D)
    - Uravan district (R. L. Boardman, W)
    - Ute Mountains (E. B. Ekren, D)
    - Wet Mountains (M. R. Brock, D)
  - Connecticut:
    - Ansonia, Milfords, Mount Carmel, and Southington quadrangles—bedrock (C. E. Fritts, D)
    - Ashaway and Voluntown quadrangles—bedrock (T. G. Feininger, Boston, Mass.)
    - Ashaway and Watch Hill quadrangles—surficial (J. P. Schafer, Boston, Mass.)
    - Bristol and New Britain quadrangles—bedrock H. E. Simpson, D)
    - Broad Brook and Manchester quadrangles (R. B. Colton, W)
    - Columbia, Fitchville, Marlboro, and Willimantic quadrangles—bedrock (G. L. Snyder, D)
    - Danielson, Hampton, Plainfield, and Scotland quadrangles—bedrock (H. R. Dixon, Boston, Mass.)
    - Durham quadrangle (H. E. Simpson, D)
    - Meriden quadrangle—bedrock (P. M. Hanshaw, Boston, Mass.)
    - Montville, Mystic, and Uncasville quadrangles—bedrock (R. Goldsmith, Boston, Mass.)
    - New Hartford quadrangle (R. W. Schnabel, D)
    - New London, Niantic, and Old Mystic quadrangles (R. Goldsmith, Boston, Mass.)
    - Southwick quadrangle (R. W. Schnabel, D)
    - Springfield South quadrangle (J. H. Hartshorn and C. Koteff, Boston, Mass.)
    - Taconic sequence (E. Zen, W)
    - Tarrifville and Windsor Locks quadrangles—bedrock (R. W. Schnabel, D)
    - Tariffville quadrangle—surficial (A. D. Randall, g, Middletown)
    - Thompson quadrangle (P. M. Hanshaw and H. R. Dixon, Boston, Mass.)
    - Watch Hill quadrangle—bedrock (G. E. Moore, Jr., Columbus, Ohio)
    - West Springfield quadrangle (R. B. Colton, W. and J. H. Hartshorn, Boston, Mass.)
  - District of Columbia, Washington metropolitan area (H. W. Coulter and C. F. Withington, W)

Geologic mapping—Continued
- Map scale 1 inch to 1 mile, and larger—Continued
  - Florida, land-pebble phosphate deposits (J. B. Cathcart, D)
  - Greenland, Schuchert Dal, East Greenland, glacial geology (J. S. Hartshorn, Boston, Mass.)
  - Idaho:
    - American Falls region (D. E. Trimble, D)
    - Aspen Range—Dry Ridge area (V. E. McKelvey, W)
    - Bancroft quadrangle (S. S. Oriel, D)
    - Big Creek quadrangle (B. F. Leonard, D)
    - Blackbird Mountain area (J. S. Vhay, Spokane, Wash.)
    - Central Idaho, radioactive placer deposits (D. L. Schmidt, W)
    - Clarks Fork and Packsaddle Mountain quadrangles (J. E. Harrison, W)
    - Coeur d'Alene mining district (S. W. Hobbs, D)
    - Doublesprings quadrangle (W. J. Mapel, D)
    - Driggs quadrangle (E. H. Pampeyan, c, M)
    - Garns Mountain quadrangle (M. H. Staatz, c, D)
    - Greenacres quadrangle (P. L. Weis, W)
    - Irwin 1, 2, 4NE and 4NW quadrangle, (D. A. Jobin, c, D)
    - Jarbidge area (R. R. Coats, M)
    - Leadore and Patterson quadrangles (E. T. Ruppel, D)
    - Morrison Lake quadrangle (E. R. Cressman, Lexington, Ky)
    - Mt. Spokane quadrangle (A. E. Weissenborn, Spokane, Wash.)
    - Orofino area (A. Hietanen-Makela, M)
    - Owyhee and Mountain City quadrangles (R. R. Coats, M)
    - Riggins quadrangle (W. B. Hamilton, D)
    - Soda Springs quadrangle (F. C. Armstrong, D)
    - Thunder Mountain niobium area (R. L. Parker, D)
    - Upper Valley quadrangle (R. L. Rioux, c, D)
    - Yellow Pine quadrangle (B. F. Leonard, D)
  - Illinois, zinc-lead mining district (J. W. Whitlow, W)
  - Indiana, Owensboro quadrangle, Quaternary geology (L. L. Ray, W)
  - Iowa, Omaha–Council Bluffs and vicinity (R. D. Miller, D)
  - Kansas:
    - Shawnee County (W. D. Johnson, Jr., Lawrence)
    - Wilson County (H. C. Wagner, M)
  - Kentucky:
    - Note: The entire State of Kentucky is being mapped geologically by 7½-minute quadrangles under a cooperative program with the Kentucky Geological Survey. Forty quadrangles have been published and 216 more are currently in progress. Project is under the supervision of P. W. Richards, Lexington, Ky. The following investigations are separate from the cooperative mapping program:
    - Eastern Kentucky coal investigations (K. J. Englund, W)
    - Jellico West and Ketchen quadrangles, Tennessee and Kentucky, (K. J. Englund, W)
    - Owensboro quadrangle, Quaternary geology (L. L. Ray, W)
    - Southern Appalachian folded belt (L. D. Harris, W)
  - Maine:
    - Aroostook County, southern (L. Pavlides, W)
    - Attean quadrangle (A. L. Albee, Pasadena, Calif.)
    - Big Lake area (D. M. Larrabee, W)
    - Greenville quadrangle (G. H. Espenshade, W)
    - Kennebago Lake quadrangle (E. L. Boudette, W)
    - Moosehead gabbro (G. H. Espenshade, W)
    - Paleozoic stratigraphy, regional (R. B. Neuman, W)
    - Stratton quadrangle, geophysical and geologic mapping (A. Griscom, W)
    - The Forks quadrangle (F. C. Canney and E. V. Post, D)
  - Maryland:
    - Allegany County (W. de Witt, Jr., W)
    - Harford County (D. Southwick, W)
    - Washington, D.C., metropolitan area (H. W. Coulter and C. F. Withington, W)
  - Massachusetts:
    - Assawompsett Pond quadrangle (C. Koteff, Boston)
    - Athol quadrangle (D. F. Eschman, Ann Arbor, Mich.)
    - Billerica, Lowell, Tyngsboro, and Westford quadrangles (R. H. Jahns, University Park, Pa.)
    - Blue Hills quadrangle (N. E. Chute, Syracuse, N.Y.)
    - Boston and vicinity (C. A. Kaye, Boston)
    - Clinton and Shrewsbury quadrangles, bedrock (R. F. Novotny, Boston)
    - Concord quadrangle (N. P. Cuppels and C. Koteff, Boston)
    - Duxbury and Scituate quadrangles (N. E. Chute, Syracuse, N.Y.)
    - Georgetown quadrangle (N. P. Cuppels, Boston)
    - Lawrence, Reading, South Groveland, and Wilmington quadrangles, bedrock (R. O. Castle, Los Angeles, Calif.)
    - Norwood quadrangle (N. E. Chute, Syracuse, N.Y.)
    - Plainfield quadrangle, bedrock (P. H. Osberg, Orono, Maine)
    - Reading and Salem quadrangles, surficial (R. N. Oldale, Boston)
    - Rowe and Heath quadrangles (A. H. Chidester, D, and J. H. Hartshorn, Boston)
    - Salem quadrangle, bedrock (P. Toulmin III, W)
    - Southwick quadrangle (R. W. Schnabel, D)
    - Springfield South quadrangle (J. H. Hartshorn and and C. Koteff, Boston)
    - Taconic sequence (E. Zen, W)
    - Taunton quadrangle (J. H. Hartshorn, Boston)
    - West Springfield quadrangle (R. B. Colton, W, and J. H. Hartshorn, Boston)
  - Michigan:
    - Dickinson County, southern (R. W. Bayley, M)
    - Gogebic Range, eastern (W. C. Prinz, W)
    - Iron County, eastern (K. L. Wier, D)
    - Iron River–Crystal Falls district (H. L. James, Minneapolis, Minn.)
    - Lake Algonquin drainage (J. T. Hack, W)
    - Marquette district, eastern (J. E. Gair, D)
    - Michigan copper district (W. S. White, W)
    - Negaunee and Palmer quadrangles (J. E. Gair, D)

Geologic mapping—Continued
- Map scale 1 inch to 1 mile, and larger—Continued
  - Minnesota:
    - Cuyuna North Range (R. G. Schmidt, W)
    - Mesabi—Vermilion Iron Range, surficial (R. D. Cotter, g, St. Paul)
  - Mississippi, Tatum salt dome (W. S. Twenhofel, D)
  - Missouri, southeastern lead deposits (T. H. Kiilsgaard, W)
  - Montana:
    - Adel NW and Craig NE quadrangles (K. S. Soward, c, Great Falls)
    - Alberton quadrangle (J. D. Wells, W)
    - Anaconda 3 NW quadrangle (A. A. Wanek, c, D)
    - Bearpaw Mountains, petrology (W. T. Pecora, W)
    - Black Butte quadrangle (A. W. Bateman, c, Great Falls)
    - Boulder batholith area (M. R. Klepper, W)
    - Browning area, Quaternary geology (G. M. Richmond, D)
    - Castagne quadrangle (H. L. Smith, c, D)
    - Clarks Fork and Packsaddle Mountain quadrangles (J. E. Harrison, W)
    - Cooney Reservoir quadrangle (A. A. Wanek, c, D)
    - Divide 2 SW quadrangle (G. D. Fraser, c, D)
    - Duck Creek Pass quadrangle (W. H. Nelson, Hopkinsville, Ky.)
    - Fort Peck area (H. D. Varnes, D)
    - Gardiner SW quadrangle (G. D. Fraser, c, D)
    - Great Falls area (R. W. Lemke, D)
    - Holter Lake quadrangle (G. D. Robinson, D)
    - Livingston—Trail Creek area (A. E. Roberts, D)
    - Maudlow quadrangle (B. A. Skipp, D)
    - Morrison Lake quadrangle (E. R. Cressman, Lexington, Ky.)
    - Neihart 1 quadrangle (W. R. Keefer, D)
    - Philipsburg area, manganese deposits (W. C. Prinz, W)
    - Powder River coal fields (N. W. Bass, D)
    - Rapids and Montaqua quadrangles (A. A. Wanek, c, D)
    - Roberts quadrangle (H. D. Zeller, c, D)
    - Roscoe NE quadrangle (E. D. Patterson, c, W)
    - Southwestern part, ore deposits (K. L. Wier, D)
    - Sun River Canyon area (M. R. Mudge, D)
    - Tepee Creek quadrangle (I. J. Witkind, D)
    - Three Forks quadrangle (G. D. Robinson, D)
    - Thunder Mountain niobium area (R. L. Parker, D)
    - Toston quadrangle (G. D. Robinson, D)
    - Varney and Cameron quadrangles (J. B. Hadley, W)
    - Willis quadrangle (W. B. Myers, D)
    - Winnett-Mosby area (W. D. Johnson, Jr., Lawrence, Kans.)
    - Wolf Creek area, petrology (R. G. Schmidt, W)
    - Wolf Point area (R. B. Colton, W)
  - Nebraska:
    - Franklin, Webster, and Nuckolls Counties (R. D. Miller, D)
    - Omaha-Council Bluffs and vicinity (R. D. Miller, D)
    - Valley County (R. D. Miller, D)

Geologic mapping—Continued
- Map scale 1 inch to 1 mile, and larger—Continued
  - Nevada:
    - Antler Peak quadrangle (R. J. Roberts, M)
    - Ash Meadows quadrangle (C. S. Denny, W)
    - Beatty area (H. R. Cornwall, M)
    - Cortez quadrangle (J. Gilluly, D)
    - Ely district (A. L. Brokaw, D)
    - Eureka, Pinto Summit, and Bellevue Peak quadrangles (T. B. Nolan, W)
    - Fallon area (R. B. Morrison, D)
    - Frenchie Creek quadrangle (L. J. P. Muffler, M)
    - Horse Creek Valley quadrangle (H. Masursky, M)
    - Humboldt Range, Unionville and Buffalo Mountain quadrangles (R. E. Wallace, M)
    - Jarbidge area (R. R. Coats, M)
    - Kobeh Valley (T. B. Nolan, W, and C. W. Merriam, M)
    - Las Vegas–Lake Mead area (C. R. Longwell, M)
    - Montello area (R. G. Wayland, c, Los Angeles, Calif.)
    - Mt. Lewis and Crescent Valley quadrangles (J. Gilluly, D)
    - Nevada Test Site, geologic studies (F. A. McKeown, D)
    - Nevada Test Site, site studies (R. E. Davis, D)
    - Nevada Test Site, underground air storage (R. B. Johnson, D)
    - Osgood Mountains quadrangle (P. E. Hotz, M)
    - Owyhee and Mountain City quadrangles (R. R. Coats, M)
    - Paradise Peak quadrangle (C. J. Vitaliano, Bloomington, Ind.)
    - Pioche district (C. M. Tschanz, La Paz, Bolivia)
    - Railroad district (J. F. Smith, Jr., D)
    - Schell Creek Range (H. D. Drewes, D)
    - Snake Range, Wheeler Peak and Garrison quadrangles (D. H. Whitebread, M)
    - Sonoma Range, northern, orogenic processes (J. Gilluly, D)
  - New Jersey:
    - Delaware River basin, lower (J. P. Owens, W)
    - Delaware River basin, middle (A. A. Drake, Jr., W)
    - Selected iron deposits (A. F. Buddington, Princeton, N.J.)
  - New Mexico:
    - Animas River area (H. Barnes, D)
    - Carrizo Mountains area (J. D. Strobell, D)
    - Franklin Mountains (R. L. Harbour, Quetta, Pakistan)
    - Gila River basin, upper part (R. B. Morrison, D)
    - Grants area (R. E. Thaden, Columbia, Ky.)
    - Laguna district (R. H. Moench, D)
    - Las Vegas quadrangle, western half (E. H. Baltz, g, Albuquerque)
    - Manzano Mountains (D. A. Myers, D)
    - Nash Draw quadrangle (L. M. Gard, D)
    - Oscura Mountains, southern part, and northern San Andres Mountains (G. O. Bachman, D)
    - Philmont Ranch quadrangle (G. D. Robinson, D)
    - Raton coal basin, eastern (G. H. Dixon, D)
    - Raton coal basin, western (C. L. Pillmore, D)
    - San Juan Basin, east side (C. H. Dane, W)
    - Silver City area (W. R. Jones, D)
    - Valles Mountains, petrology (R. L. Smith, W)

Geologic mapping—Continued
Map scale 1 inch to 1 mile, and larger—Continued
New York:
Dannemora and Plattsburgh quadrangles, surficial geology (C. S. Denny, W)
Elmira-Williamsport area, glacial geology (C. S. Denny, W)
Gouverneur area, metamorphism and origin of mineral deposits (A. E. J. Engel, La Jolla, Calif.)
Mooers and Ohio quadrangles (D. R. Wiesnet, W)
Richville quadrangle (H. M. Bannerman, W)
Selected iron deposits (A. F. Buddington, Princeton, N.J.)
Taconic sequence (E. Zen, W)
North Carolina:
Central Piedmont (H. Bell, W)
Franklin quadrangle (F. G. Lesure, W)
Grandfather Mountain (B. H. Bryant, D)
Great Smoky Mountains (J. B. Hadley, W)
Hamme tungsten deposit (J. M. Parker 3d, Raleigh)
Morganton area, geomorphic studies (J. T. Hack, W)
Mount Rogers area (D. W. Rankin, W)
Shelby quadrangle (W. C. Overstreet, W)
Swain County copper district (G. H. Espenshade, W)
Volcanic Slate series (A. A. Stromquist, D)
North Dakota, New Salem 2 SW quadrangle (H. L. Smith, c, D)
Ohio, Belmont County (H. L. Berryhill, Jr., D)
Oklahoma, Ft. Smith district (T. A. Hendricks, D)
Oregon:
Bandon SE and Coquille SW quadrangles (E. M. Baldwin, c, Los Angeles, Calif.)
John Day area (T. P. Thayer, W)
Monument quadrangle (R. E. Wilcox, D)
Newport Embayment (P. D. Snavely, Jr., M)
Ochoco Reservation, Lookout Mountain, Eagle Rock, and Post quadrangles (A. C. Waters, Baltimore, Md.)
Portland industrial area (D. E. Trimble, D)
Pacific Islands:
Bikini and nearby atolls (H. S. Ladd, W)
Guam (J. I. Tracey, Jr., W)
Ishigaki, Ryukyu Islands (H. L. Foster, W)
Okinawa (G. Corwin, W)
Pagan Island (G. Corwin, W)
Palau Islands (G. Corwin, W)
Yap and Caroline Islands (C. G. Johnson, Honolulu, Hawaii)
Pennsylvania:
Anthracite mine-drainage projects, geology in the vicinity of (J. F. Robertson, Mt. Carmel)
Anthracite region, flood control (M. J. Bergin, Mt. Carmel)
Bituminous coal resources (E. D. Patterson, W)
Delaware River basin, lower (J. P. Owens, W)
Delaware River basin, middle (A. A. Drake, Jr., W)
Devonian stratigraphy of State (G. W. Colton, W)
Elmira-Williamsport area, glacial geology (C. S. Denny, W)

Geologic mapping—Continued
Map scale 1 inch to 1 mile, and larger—Continued
Pennsylvania—Continued
Lehighton quadrangle (H. Klemic, Bowling Green, Ky.)
Philadelphia district, Lower Cambrian (J. H. Wallace, W)
Southern anthracite field (G. H. Wood, Jr., W)
Washington County (H. L. Berryhill, Jr., D)
Western Middle anthracite field (H. Arndt, W)
Puerto Rico (W. H. Monroe, San Juan, Puerto Rico)
Rhode Island:
Ashaway and Voluntown quadrangles (T. G. Feininger, Boston, Mass.)
Ashaway and Watch Hills quadrangles, surficial (J. P. Schafer, Boston, Mass.)
Carolina and Quonochontaug quadrangles, surficial (J. P. Schafer, Boston, Mass.)
Chepachet, Crompton, and Tiverton quadrangles, bedrock (A. W. Quinn, Providence)
Clayville, Coventry Center, Kingston, Newport, and Prudence Island quadrangles, bedrock (G. E. Moore, Jr., Columbus, Ohio)
Thompson quadrangle (P. M. Hanshaw and H. R. Dixon, Boston, Mass.)
Watch Hill quadrangle, bedrock (G. E. Moore, Jr., Columbus, Ohio)
Wickford quadrangle, bedrock (R. B. Williams, Lawrence, Kans.)
South Dakota:
Black Hills, southern (G. B. Gott, D)
Fort Randall Reservoir area (H. D. Varnes, D)
Harding County and adjacent areas (G. N. Pipiringos, D)
Hill City pegmatite area (J. C. Ratté, D)
Keystone pegmatite area (J. J. Norton, W)
Rapid City area (E. Dobrovolny, D)
Tennessee:
Ducktown district and adjacent areas (R. M. Hernon, D)
East Tennessee zinc studies (A. L. Brokaw, D)
Great Smoky Mountains (J. B. Hadley, W)
Ivydell and Pioneer quadrangles, Tennessee, and Jellico West and Ketchen quadrangles, Tennessee and Kentucky (K. J. Englund, W)
Knoxville and vicinity (J. M. Cattermole, Columbia, Ky.)
Mount Rogers area (D. W. Rankin, W)
Southern Appalachian folded belt, Kentucky, Tennessee, and Virginia (L. D. Harris, W)
Texas:
Coastal plain, geophysical and geological studies (D. H. Eargle, Austin)
Del Rio area (V. L. Freeman, D)
Franklin Mountains (R. L. Harbour, Quetta, Pakistan)
North-central Texas, Pennsylvanian Fusulinidae (D. A. Myers, D)
Sierra Blanca area (J. F. Smith, Jr., D)
Sierra Diablo region (P. B. King, M)
Utah:
Abajo Mountains (I. J. Witkind, D)
Alta quadrangle (M. D. Crittenden, Jr., M)
Bingham Canyon district (R. J. Roberts, M)

Geologic mapping—Continued
- Map scale 1 inch to 1 mile, and larger—Continued
  - Utah—Continued
    - Circle Cliffs area (E. S. Davidson, Tucson, Ariz.)
    - Coal-mine bumps (F. W. Osterwald, D)
    - Confusion Range (R. K. Hose, M)
    - Crawford Mountains (W. C. Gere, c, Salt Lake City)
    - Deer Flat area, White Canyon district (T. L. Finnell, D)
    - Elk Ridge area (R. Q. Lewis, Columbia, Ky.)
    - Green River valley, upper part (W. R. Hansen, D)
    - Hurricane fault, southwestern Utah (P. Averitt, D)
    - Kolob Terrace coal field, southern part (W. B. Cashion, D)
    - La Sal area (W. D. Carter, W)
    - Lehi quadrangle (M. D. Crittenden, Jr., M)
    - Lisbon Valley area (G. W. Weir, Berea, Ky.)
    - Little Cottonwood area (G. M. Richmond, D)
    - Moab-Interriver area (E. N. Hinrichs, D)
    - Navajo Reservation, fuels potential (R. B. O'Sullivan, D)
    - Nipple Butte quadrangle (H. A. Waldrop, c, D)
    - Oak City area (D. J. Varnes, D)
    - Ogden 4 quadrangle (T. A. Mullens, c, D)
    - Orange Cliffs area (F. A. McKeown, D)
    - Park City area (M. D. Crittenden, Jr., M)
    - Park City district, ore deposits (C. S. Bromfield, D)
    - Promontory Point (R. B. Morrison, D)
    - Sage Plain area (L. C. Huff, Manila, P.I.)
    - Salt Lake City and vicinity (R. Van Horn, D)
    - San Francisco Mountains (D. M. Lemmon, M)
    - San Rafael Swell (C. C. Hawley, D)
    - Sheeprock Mountains, West Tintic district (H. T. Morris, M)
    - Snake Range, Wheeler Peak and Garrison quadrangles (D. H. Whitebread, M)
    - Strawberry Valley and Wasatch Mountains (A. A. Baker, W)
    - Thomas and Dugway Ranges (M. H. Staatz, D)
    - Tintic lead-zinc district, eastern (H. T. Morris, M)
    - Uinta Basin oil shale (W. B. Cashion, D)
    - White Canyon area (R. E. Thaden, Columbia, Ky.)
  - Vermont:
    - North-central Vermont (W. M. Cady, D)
    - Rowe and Heath quadrangles (A. H. Chidester, D, and J. H. Hartshorn, Boston, Mass.)
  - Virginia:
    - Big Stone Gap district (R. L. Miller, W)
    - Herndon quadrangle (R. E. Eggleton, M)
    - Mount Rogers area (D. W. Rankin, W)
    - Potomac Basin studies (J. T. Hack, W)
    - Southern Appalachian folded belt (L. D. Harris, W)
    - Washington, D.C., metropolitan area (H. W. Coulter and C. F. Withington, W)
  - Washington:
    - Bald Knob quadrangle (M. H. Staatz, D)
    - Bodie Mountain quadrangle (R. C. Pearson, D)
    - Glacier Peak quadrangle (D. F. Crowder, M)
    - Grays Harbor basin, western part (H. C. Wagner, M)
    - Holden and Lucerne quadrangles (F. W. Cater, D)

Geologic mapping—Continued
- Map scale 1 inch to 1 mile, and larger—Continued
  - Washington—Continued
    - Hunters quadrangle (A. B. Campbell, D)
    - Inchelium quadrangle (A. B. Campbell, D)
    - Maple Valley, Hobart and Cumberland quadrangles (J. D. Vine, M)
    - Metaline lead-zinc district (M. G. Dings, D)
    - Mt. Spokane quadrangle (A. E. Weissenborn, Spokane)
    - Olympic Peninsula, eastern (W. M. Cady, D)
    - Olympic Peninsula, northern (R. D. Brown, Jr., W)
    - Portland industrial area (D. E. Trimble, D)
    - Puget Sound Basin (D. R. Crandell, D)
    - Republic-Curlew area (R. L. Parker, D)
    - Seattle and vicinity (D. R. Mullineaux, D)
    - Stevens County (R. G. Yates, M)
    - Turtle Lake quadrangle (G. E. Becraft, D)
    - Wilmont Creek quadrangle (G. E. Becraft, D)
  - West Virginia, Potomac Basin studies (J. T. Hack, W)
  - Wisconsin:
    - Florence County (C. E. Dutton, Madison)
    - Zinc-lead mining district (J. W. Whitlow, W)
  - Wyoming:
    - Adam Weiss Peak quadrangle (W. L. Rohrer, c, D)
    - Atlantic City district (R. W. Bayley, M)
    - Baggs area (G. E. Prichard, D)
    - Beaver Divide area (F. B. Van Houten, Princeton, N.J.)
    - Big Piney area (S. S. Oriel, D)
    - Carbon and Northern Laramie basins (H. J. Hyden, c, D)
    - Clark, Deep Lake, and Beartooth Butte quadrangles (W. G. Pierce, M)
    - Cokeville quadrangle (W. W. Rubey, Los Angeles, Calif.)
    - Crawford Mountains (W. C. Gere, c, Salt Lake City, Utah)
    - Crooks Gap area (J. G. Stephens, D)
    - Crowheart Butte area (J. F. Murphy, D)
    - East Thermopolis area (G. H. Horn, c, D)
    - Ferris quadrangle (R. L. Rioux, c, D)
    - Fish Lake and Kissinger Lakes quadrangles (W. L. Rohrer, c, D)
    - Fort Hill quadrangle (S. S. Oriel, D)
    - Fossil basin (J. I. Tracey, Jr., W)
    - Gas Hills district (H. D. Zeller, D)
    - Grand Teton National Park (J. D. Love, Laramie)
    - Black Hills, Inyan Kara Group (W. J. Mapel, D)
    - LaBarge 1 SW and 2 SE quadrangles (R. L. Rioux, c, W)
    - Oregon Buttes area (H. D. Zeller, c, D)
    - Powder River Basin, Pumpkin Buttes area (W. N. Sharp, D)
    - Powder River Basin, southern part (W. N. Sharp, D)
    - Riddle Cut quadrangle (H. McAndrews, c, Casper)
    - Sheep Mountain and Tatman Mountain quadrangles (W. L. Rohrer, c, D)
    - Shirley Basin area (E. N. Harshman, D)
    - Shotgun Butte (W. R. Keefer, Laramie)
    - Spence-Kane area (R. L. Rioux, c, D)
    - Sweetwater County, Green River Formation (W. C. Culbertson, D)

Geophysics, regional—Continued
- California:
  - Los Angeles basin, gravity study (T. H. McCulloh, Riverside)
  - Sacramento Valley and Coast Range, geophysical studies (G. D. Bath, M)
  - San Francisco Bay area, geophysical studies (G. D. Bath, M)
  - Sierra Nevada, geophysical studies (H. W. Oliver, M)
- Colorado, Arkansas Valley, geophysical study (J. E. Case, D)
- Iowa, central, aeromagnetic survey (J. R. Henderson, W)
- Kentucky, geophysical studies (J. S. Watkins, W)
- Maine:
  - Island Falls quadrangle, electromagnetic mapping (F. C. Frischknecht, W)
  - Stratton quadrangle, geophysical and geologic mapping (A. Griscom, W)
- Maryland, Montgomery County, geophysical studies (A. Griscom, W)
- Massachusetts:
  - Application of geology and seismology to public-works planning (C. R. Tuttle and R. N. Oldale, Boston)
  - Geophysical studies (R. W. Bromery, W)
- Michigan:
  - Gogebic district, aeromagnetic study (J. E. Case, D)
  - Marquette district, aeromagnetic study (J. E. Case, D)
- Mississippi, Tatum salt dome (W. S. Twenhofel, D)
- Missouri, southeast, aeromagnetic study (J. W. Allingham, W)
- Montana:
  - Bearpaw Mountains, aeromagnetic study (K. G. Books, W)
  - Boulder batholith, aeromagnetic and gravity studies (W. E. Davis, M)
- Nevada:
  - Central Nevada, geophysical studies (D. R. Mabey, M)
  - Clark County, gravity investigations (M. F. Kane, W)
  - Nevada Test Site, aeromagnetic surveys (J. W. Allingham, W)
  - Nevada Test Site, soil conductivity measurements (J. H. Scott, D)
- New Jersey, New York-New Jersey Highlands, aeromagnetic studies (A. Jespersen, W)
- New Mexico, Valles caldera, geophysical study (H. R. Joesting, W)
- New York:
  - Adirondacks area, aeromagnetic studies (J. R. Balsley, Middleton, Conn.)
  - New York-New Jersey Highlands, aeromagnetic studies (A. Jespersen, W)
- North Carolina, Concord quadrangle, geophysical studies (R. G. Bates, W)
- Ohio, seismic survey for buried valleys (J. S. Watkins, W)
- Oregon:
  - Oregon Cascades, geophysical study (H. R. Blank, M)
  - West-central Oregon, aeromagnetic and gravity studies (R. W. Bromery, W)
- Pennsylvania, Triassic area, aeromagnetic study (R. W. Bromery, W)
- Puerto Rico, geophysical studies (A. Griscom, W)
- South Dakota, Black Hills area, regional gravity studies (R. M. Hazlewood, D)
- Tennessee, central eastern, geophysical studies (J. S. Watkins, W)

Geophysics, regional—Continued
- Texas, coastal plain, geophysical and geological studies (D. H. Eargle, Austin)
- Utah, Iron Springs, aeromagnetic survey (H. R. Blank, M)
- Washington:
  - Northeastern, geophysical studies (W. T. Kinoshita, M)
  - Western, gravity survey (D. J. Stuart, D)
- Wisconsin:
  - Florence County, aeromagnetic study (E. R. King, W)
  - Wausau area, aeromagnetic studies (J. W. Allingham, W)
- Wyoming, Black Hills area, regional gravity studies (R. M. Hazlewood, D)

Geophysics, theoretical and experimental:
- Elastic and inelastic properties of earth materials (L. Peselnick, W)
- Electric and magnetic properties of minerals (A. N. Thorpe, W)
- Electrical effects of nuclear explosions (G. V. Keller, D)
- Electrical methods, development (C. J. Zablocki, D)
- Electrical properties of rocks (G. V. Keller, D)
- Electromagnetic exploration methods (F. C. Frischknecht, W)
- Geophysical abstracts (J. W. Clarke, W)
- Geophysical data, interpretation using electronic computers (R. G. Henderson, W)
- Gravity and magnetic anomalies, analysis (W. H. Diment, W)
- Heat flow and thermal properties (A. H. Lachenbruch, M)
- Heat flow in the Appalachian Mountains (W. H. Diment, W)
- Heat transfer in salt (E. C. Robertson, W)
- Ice strength (D. F. Barnes, M)
- Infrared and ultraviolet radiation studies (R. M. Moxham, W)
- Magnetic model studies (I. Zietz, W)
- Magnetic properties of rocks (A. Griscom, W)
- Nevada Test Site, soil conductivity measurements (J. H. Scott, D)
- Propagation of seismic waves in porous media (J. A. daCosta, g, Phoenix, Ariz.)
- Radon, geologic behavior (A. B. Tanner, W)
- Remanent magnetization of rocks (R. R. Doell, M)
- Remote sensing (W. A. Fischer, W)
- Remote sensing of hydrologic phenomena (C. J. Robinove, g, St. Louis, Mo.)
- Rock behavior at high temperature and pressure (E. C. Robertson, W)
- Tension fractures and thermal investigation (A. H. Lachenbruch, M)
- Thermodynamic properties of rocks (R. A. Robie, W)
- Tiltmeter investigations (G. W. Greene, M)
- Ultramafic intrusions, geophysical studies (G. A. Thompson, M)

Glaciology:
- Barrier Glacier (Mount Spurr), Alaska (G. C. Giles, c, Tacoma, Wash.)
- Glaciological research (M. F. Meier, h, Tacoma, Wash.)
- Grinnell and Sperry Glaciers (Glacier National Park), Mont. (A. Johnson, c, W)
- Hydrology of Grinnell Glacier, Mont. (F. Stermitz, s, Helena)
- Nisqually Glacier (Mount Rainier National Park), Wash. (G. C. Giles, c, Tacoma)

Glacial geology:
- Alaska, glacial map (H. W. Coulter, W)
- Antarctica Pensacola Mountains (A. B. Ford, W)
- California, west-central Sierra Nevada (F. M. Fryxell, Rock Island, Ill.)
- Greenland, Schuchert Dal (J. S. Hartshorn, Boston, Mass.)
- New York and Pennsylvania, Elmira-Williamsport area (C. S. Denny, W)

Gold:
- Gold deposits, United States (M. H. Bergendahl, D)
- Alaska:
  - Nome C–1 and D–1 quadrangles (C. L. Hummel, M)
  - Tofty placer district (D. M. Hopkins, M)
- Colorado, Tenmile Range and Kokomo mining district (M. H. Bergendahl, D)
- Wyoming, Atlantic City district (R. W. Bayley, M)

Ground water-surface water relations:
- Bank-seepage studies (E. C. Pogge, s, Iowa City, Iowa)
- Bank storage, Hungry Horse Reservoir, Mont. (A. F. Bate-men, Jr., c, Great Falls)
- Cedar River loss study, Washington, surface and ground water (F. T. Hidaka, s, Tacoma)
- Flow losses in ephemeral stream channels (R. F. Hadley, h, D)
- Ground water-surface water interrelations (M. W. Busby, s, Topeka, Kans.)
- Relationship of ground-water storage and streamflow, Columbia River basin (M. I. Rorabaugh, g, Tacoma, Wash.)
- Water-loss and water-gain studies in California (J. R. Crippen, s, M)

Health, relation to distribution of elements:
- Distribution of radioactivity (S. Rosenblum, W)

Hydraulics, ground water:
- Aquifer-test reevaluation, California (E. J. McClelland, g, Sacramento)
- Directional permeability and nonhomogeneity, mathematical relations (J. A. DaCosta, g, Phoenix, Ariz.)
- Directional permeability of marine sandstones (R. R. Bennett, g, W)
- Effects of heterogeneity (H. E. Skibitzke, g, Phoenix, Ariz.)
- Mechanics of aquifers—principles of compaction and deformation (J. F. Poland, g, Sacramento, Calif.)
- Mechanics of diffusion, fresh and salt water (H. H. Cooper, g, Tallahassee, Fla.)
- Mechanics of fluid flow in porous media (A. Ogata, g, Honolulu, Hawaii)
- Permeability research, California (A. I. Johnson, g, D)
- Theory of multiphase flow—applications (R. W. Stallman, g, D)
- Theory of unsaturated flow (H. E. Skibitzke, g, Phoenix, Ariz.)
- Transient flow in saturated porous media (W. O. Smith, g, W)
- Treatise on ground-water mechanics (J. G. Ferris, g, Tucson, Ariz.)
- Unsaturated flow, National Reactor Testing Station, Idaho (P. H. Jones, g, Boise)
- Unsaturated flow in porous media (W. O. Smith, g, W)
- Unsaturated-flow theory related to drainage and infiltration (Jacob Rubin, h, M)
- Unsteady flow to multiaquifer wells (I. S. Papadopulos, g, Trenton, N.J.)

Hydraulics, surface flow:
- Changes below dams—river channels (M. G. Wolman, h, Baltimore, Md.)
- Discharge rating for streams (W. S. Eisenlohr, Jr., h, D)
- Dispersion by turbulent flow in open channels (R. W. Carter, s, W)
- Distribution of shear (D. I. Cahal, s, W)
- Extension of rating curves (R. H. Tice, s, Trenton, N.J.)
- Flow through wide constrictions (F. Chang, s, Atlanta, Ga.)
- Gaging streamflow through turbines (B. J. Frederick, w, Chattanooga, Tenn.)
- Large-scale roughness (J. Davidian, s, W)
- Scour of river beds during high flow (L. B. Leopold, w, W)
- Time of travel, Rockaway River, N.J. (E. L. Meyer, s, W)
- Time-of-travel studies (B. Dunn, s, Albany, N.Y.)
- Unsteady flow in natural channels (C. Lai, s, W)
- Variation in velocity-head coefficient (H. Hulsing, s, M)
- Verification of hydraulic techniques (W. J. Randolph, w, Chattanooga, Tenn.)
- Vertical-velocity characteristics of Columbia River gaging stations, Washington (G. L. Bodhaine, J. Savini, s, Tacoma)

Hydrologic-data collection and processing:
- Adjustment of the Delaware River discharge records for storage, diversion, and evaporation (E. G. Miller, s, Trenton)
- Analysis of water-level records in Pennsylvania (C. W. Poth, g, Harrisburg)
- Automation and processing techniques for water-quality data (G. A. Billingsley, q, Raleigh, N.C.)
- Correlation of monthly streamflow (R. O. R. Martin, s, W)
- Drainage-area compilation, Kentucky (H. C. Beaber, s, Louisville)
- Drainage-area determinations, South Carolina (W. M. Bloxham, s, Columbia)
- Drainage-area determinations, Texas (P.H. Holland, s, Austin)
- Drainage-area measurement, Arkansas (R.C. Christensen, s, Little Rock)
- Flood and base-flow gaging, New Jersey (E. G. Miller, s, Trenton)
- Methods used in measurement and analysis of sediment loads in streams (B. C. Colby, q, Minneapolis, Minn.)
- New criteria for data-collection program (M. A. Benson, s, W)
- River-systems gaging (H. C. Riggs, s, W)
- Sediment manual (R. B. Vice, q, W)
- Systems and equipment for automation—water (W. L. Isherwood, s, W)
- Statistical inferences (N. C. Matalas, s, W)
- Use of ponds to measure rates of storm runoff in Louisiana (R. Sloss, s, Baton Rouge)
- Vigil Network Survey—observations of channel and slope processes (W. W. Emmett and L. B. Leopold, w, W)

Hydrologic instrumentation:
- Acoustic velocity-measuring equipment—water (W. Hofmann, s, M)
- Development of instrumentation to study unstable flow in steep channels (W. Smith, s, M)
- Electronic-equipment development—water (J. E. Eddy, g, W)

Hydrologic instrumentation—Continued
- Evaluation equipment for brine disposal, Eddy County, N. Mex. (E. R. Cox, g, Albuquerque)
- Instruments for energy-budget evaporation studies (C. R. Daum, s, D)
- Instruments for laboratory research—water (G. F. Smoot, s, W)
- Instrumentation research—water (E. G. Barron, s, Columbus, Ohio)

Hydrology, ground-water:
- Geohydrologic environmental study (J. N. Payne, g, Baton Rouge, La.)
- Geologic and hydrologic profile along the Chattahoochee River, Ala. (L. D. Toulmin, g, Tuscaloosa)
- Geologic and hydrologic profile in Clarke County, Ala. (L. D. Toulmin, g, Tuscaloosa)
- Hydrology of Alabama oil fields (W. J. Powell, g, Tuscaloosa)
- Mechanics of aquifers, San Joaquin–Santa Clara Valleys, Calif. (J. F. Poland, g, Sacramento)
- Problems in quantitative hydrology (M. I. Rorabaugh, g, Tacoma, Wash.)
- Specific-yield studies, California (A. I. Johnson, g, D)
- Water-table and engineering mapping, Delaware, statewide (D. H. Boggess, g, Newark)

Hydrology, surface-water:
- Diurnal fluctuations of streams, New York (F. L. Robison, s, Albany)
- Effect of farm ponds on streamflow, Ohio (W. P. Cross, s, Columbus)
- Effect of logging on runoff in upper Green River basin, Washington (D. Richardson, s, Tacoma)
- Effect of wind on Franklin D. Roosevelt Lake, Wash. (E. G. Nassar, s, Tacoma)
- Flow probability of New Jersey streams (E. G. Miller, s, Trenton)
- Hydrologic and hydraulic studies, Virginia (C. W. Lingham, s, Charlottesville)
- Hydrology of small streams, New Hampshire (C. E. Knox, s, Boston, Mass.)
- Lake mapping and stabilization, Indiana (D. C. Perkins, s, Indianapolis)
- Land-use evaluation (F. W. Kennon, s, Austin, Tex.)
- Long-term chronologies of hydrologic events (W. D. Simons, s, Tacoma, Wash.)
- Natural diurnal fluctuations in streams (R. E. Oltman, s, W)
- Optimum discharge for salmon spawning as related to streamflow characteristics (S. E. Rantz, s, M)
- Peak inflow and outflow through ponds (J. E. McCall, s, Trenton, N.J.)
- Small streams, Alabama (L. B. Peirce, s, Tuscaloosa)
- Snow melt hydrology of a Sierra Nevada stream (S. E. Rantz, s, M)
- Stream profiles, Alabama (L. B. Peirce, s, Tuscaloosa)
- Unit graphs and infiltration rates, Alabama (L. B. Peirce, s, Tuscaloosa)
- Variations in streamflow, Utah (G. L. Whitaker, s, Salt Lake City)
- Variations in streamflow due to earthquakes, Utah (W. N. Jibson, s, Salt Lake City)
- Verification of hydraulic and hydrologic design factors, Montlemar Creek (Wragg Swamp canal), Alabama (L. H. Terry, s, Tuscaloosa)

Iron:
- Clinton iron ores of the southern Appalachians (R. P. Sheldon, D)
- Alaska, Klukwan iron district (E. C. Robertson, W)
- Michigan:
  - Dickinson County, southern (R. W. Bayley, M)
  - Gogebic Range, eastern (W. C. Prinz, W)
  - Iron County, eastern (K. L. Wier, D)
  - Iron River–Crystal Falls district (H. L. James, Minneapolis, Minn.)
  - East Marquette district (J. E. Gair, D)
  - Negaunee and Palmer quadrangles (J. E. Gair, D)
- Minnesota, North Cuyuna range (R. G. Schmidt, W)
- Montana, southwestern (K. L. Wier, D)
- New Jersey and New York, selected iron deposits (A. F. Buddington, Princeton, N.J.)
- Tennessee, Ducktown district and adjacent areas (R. M. Hernon, D)
- Wisconsin, Florence County (C. E. Dutton, Madison)
- Wyoming, Atlantic City district (R. W. Bayley, M)

Isotope and nuclear studies:
- Isotope geology of lead (A. P. Pierce, D)
- Isotopic hydrology (G. L. Stewart, q, W)
- Isotope ratios in rocks and minerals (I. Friedman, W)
- Isotopic studies of crustal processes (B. Doe, W)
- Light stable isotopes (I. Friedman, W)
- Magnetic-acoustic studies (F. E. Senftle, W)
  - Nuclear irradiation (C. M. Bunker, D)
- Oxygen-isotope geothermometry (H. L. James, Minneapolis, Minn.)
- Radiation-damage studies (F. E. Senftle, W)
- Radioactive nuclides in minerals (F. E. Senftle, W)
- Tritium, Lake McMillan underground reservoir, New Mexico (H. O. Reeder, g, Albuquerque)
- Tritium, Ogallala Formation, in the High Plains, Lea County, N. Mex. (H. O. Reeder, g, Albuquerque)
- Tritium concentrations in precipitation, surface waters and ground waters of the coastal plain of New Jersey (E. C. Rhodehamel, g, Trenton)
- Tritium in ground water, Roswell Basin, N. Mex. (W. A. Mourant, g, Albuquerque)
- *See also* Geochronology.

Lake levels:
- Elevations of Great Salt Lake (L. N. Jorgensen, s, Salt Lake City, Utah)

Land subsidence:
- Land-subsidence studies, San Joaquin Valley, Calif. (J. F. Poland, g, Sacramento)

Lead and zinc:
- Mississippi Valley type ore deposits, origin (A. V. Heyl, W)
- Western oxidized-zinc deposits (A. V. Heyl, W)
- Zinc resources of the world (T. H. Kiilsgaard, W)
- Arizona, Lochiel and Nogales quadrangles (F. S. Simons, D)
- California, Panamint Butte quadrangle (W. E. Hall, W)
- Colorado, Rico district (E. T. McKnight, W)
- Idaho, Coeur d'Alene mining district (S. W. Hobbs, D)
- Illinois, Wisconsin zinc-lead mining district (J. W. Whitlow, W)
- Kansas, Picher lead-zinc district (E. T. McKnight, W)
- Missouri:
  - Picher lead-zinc district (E. T. McKnight, W)
  - Southeastern part (T. H. Kiilsgaard, W)
- Nevada:
  - Ely district (A. L. Brokaw, D)
  - Pioche district (C. M. Tschanz, La Paz, Bolivia)

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Uranium—Continued
- South Dakota:
  - Harding County and adjacent areas (G. N. Pipiringos, D)
  - Southern Black Hills (G. B. Gott, D)
- Texas, coastal plain, geophysical and geological studies (D. H. Eargle, Austin)
- Utah:
  - Deer Flat area, White Canyon district (T. L. Finnell, D)
  - La Sal area (W. D. Carter, W)
  - Lisbon Valley area (G. W. Weir, Berea, Ky.)
  - Sage Plain area (L. C. Huff, Manila, P. I.)
  - San Rafael Swell (C. C. Hawley, D)
  - White Canyon area (R. E. Thaden, Columbia, Ky.)
- Washington, Mt. Spokane quadrangle (A. E. Weissenborn, Spokane)
- Wyoming:
  - Baggs area (G. E. Prichard, D)
  - Central Wyoming, selected uranium deposits (F. C. Armstrong, D)
  - Crooks Gap area (J. G. Stephens, D)
  - Gas Hills district (H. D. Zeller, D)
  - Powder River Basin, Pumpkin Buttes area (W. N. Sharp, D)
  - Powder River Basin, southern part (W. N. Sharp, D)
  - Shirley Basin area (E. N. Harshman, D)

Urban development. *See* Construction and terrain problems.

Urbanization, hydrologic effects:
- Effects of urbanization on hydrology (F. J. Keller, q, W)
- Hydrologic effects of urbanization (A. O. Waananen, s, M)
- Urban runoff, Turtle Creek, Tex. (C. R. Gilbert, s, Austin)
- Urban runoff, Waller Creek, Tex. (W. H. Espey, Jr., s, Austin)

Vanadium:
- Colorado Plateau, uranium-vanadium deposits in sandstone (R. P. Fischer, D)
- Commodity studies (R. P. Fischer, D)
- Vanadium geology and resources, bibliography (J. P. Ohl, D)
- Colorado:
  - Bull Canyon district (C. H. Roach, D)
  - La Sal area (W. D. Carter, W)
  - Lisbon Valley area (G. W. Weir, Berea, Ky.)
  - Slick Rock district (D. R. Shawe, D)
  - Uravan district (R. L. Boardman, W)
- Utah:
  - La Sal area (W. D. Carter, W)
  - Lisbon Valley area (G. W. Weir, Berea, Ky.)
  - Sage Plain area (L. C. Huff, Manila, P.I.)

Vegetation:
- Alaska, vegetation map (L. A. Spetzman, W)
- Pacific Islands vegetation (F. R. Fosberg, W)
- Plant analysis laboratory (F. N. Ward, D)
- *See also* Evapotranspiration *and* Plant ecology.

Volcanology:
- Alaska, Katmai National Monument, petrology and volcanism (G. H. Curtis, M)
- Hawaii, volcanology (J. G. Moore, Hawaii)
- Idaho, central Snake River Plain, volcanic petrology (H. A. Powers, D)

Volcanology—Continued
- Montana:
  - Bearpaw Mountains, petrology (W. T. Pecora, W)
  - Valles Mountains, petrology (R. L. Smith, W)
  - Wolf Creek area, petrology (R. G. Schmidt, W)
- Pacific Coast basalts, geochemistry (K. J. Murata, M)
- Silicic ash beds, correlation (H. A. Powers, D)

Volcanic-terrane hydrology:
- Columbia River Basalt, hydrology (R. C. Newcomb, g, Portland, Oreg.)

Water management:
- Role of water in determining the economic destiny of the Pacific Northwest (G. L. Bodhaine, s, Tacoma, Wash.)
- Water management (C. W. Reck, s, W)

Water resources:
- Hydrology of glacial terrane in the Great Lakes area (R. Schneider, g, W)
- Hydrology of small basins, public domain, Western States (H. V. Peterson, h, M)
- Lower Colorado River basin, hydrology (C. C. McDonald, g, Tucson, Ariz.)
- Mississippi Embayment, hydrology (E. M. Cushing, g, Chattanooga, Tenn.)
- Summary of the ground-water situation in the United States (C. L. McGuinness, g, W)
- Water resources in the Permian Basin (D. W. Greenman, w, Austin, Tex.)
- Water-supply exploration on the public domain, Pacific coast area (C. T. Snyder, h, M)
- Water-supply exploration on the public domain, Rocky Mountain area (N. J. King, h, D)
- Alabama (Tuscaloosa):
  - Hydrologic atlas of the State (C. F. Hains, s)
  - Hydrologic study of the Tuscaloosa area (K. D. Wahl, g)
  - Ground water:
    - Autauga County (J. C. Scott, g)
    - Bullock County (J. C. Scott, g)
    - Calhoun County (J. C. Warman, g)
    - Cherokee County (L. V. Causey, g)
    - Dallas County (J. C. Scott, g)
    - Escambia County (J. W. Cagle, g)
    - Hale County (T. H. Sanford, g)
    - Huntsville and Madison County (T. H. Sandford, g)
    - Lawrence County (W. F. Harris, g)
    - Marshall County (T. H. Sanford, g)
    - Morgan County (C. L. Dodson, g)
    - Pickens County (K. D. Wahl, g)
    - Russell County (J. C. Scott, g)
    - Russellville and vicinity (R. R. Peace, g)
    - St. Clair County (L. V. Causey, g)
    - Sylacauga area (G. W. Swindel, g)
    - Talladega County (L. V. Causey, g)
  - Surface-water resources, Calhoun County (J. R. Harkins, s)
  - Surface-water resources and hydrology of southwest Alabama (L. B. Peirce, s)
  - Surface-water resources and hydrology of the Tennessee Valley (J. R. Harkins, s)

Water resources—Continued
- Alaska (Anchorage):
  - Ground water:
    - Chugiak area (R. M. Waller, g)
    - General inventory (R. M. Waller, g)
    - Homer area (R. M. Waller, g)
    - Investigations for U.S. National Park Service (R. M. Waller, g)
    - Water-resources records for Anchorage (R. M. Waller, g)
    - Water-supply investigations for the U.S. Air Force (A. J. Feulner, g)
- American Samoa (Honolulu, Hawaii):
  - Ground water (K. J. Takasaki, g)
- Arizona (Tucson):
  - Sycamore Creek basin, water resources (B. Thompson, s)
  - Ground water:
    - Apache County, central (J. P. Akers, g)
    - Beardsley area (W. Kam, g)
    - Big Sandy Valley (W. Kam, g)
    - Dateland-Hyder area (P. W. Johnson, g)
    - Flagstaff area (J. P. Akers, g)
    - Fort Huachuca (S. G. Brown, g)
    - Luke Air Force Base (R. S. Stulik, g)
    - Navajo Indian Reservation (M. E. Cooley, g)
    - Papago Indian Reservation (L. A. Heindl, g, W)
    - Pinal County, northwestern (W. F. Hardt, g)
    - Safford area (E. S. Davidson, g)
    - San Simon basin (N. D. White, g)
    - Tucson basin (E. F. Pashley, Jr., g)
    - Verde Valley (F. R. Twenter, g)
    - Willcox basin (S. G. Brown, g)
- Arkansas (Little Rock):
  - Ground water:
    - Arkansas River valley (M. S. Bedinger, g)
    - Along U.S. Highway 67 (H. N. Halberg, g)
    - Along U.S. Highway 70 from Pulaski County to Crittenden County (H. N. Halberg, g)
    - Jackson-Independence area (J. E. Reed, g)
    - Ouachita Mountains (D. R. Albin, g)
    - Pulaski-Saline Counties (R. O. Plebuch, g)
    - Ouachita Mountains (D. R. Albin, g)
  - Ground water:
    - Antelope Valley–East Kern Water Agency (J. E. Weir, Jr., g)
    - Camp Pendleton Marine Corps Base (J. S. Bader, g)
    - Death Valley National Monument, Wildrose-Grapevine area (J. J. French, g)
    - Edwards Air Force Base (W. R. Moyle, g)
    - Inyokern Naval Ordnance Test Station (F. Kunkel, g)
    - Joshua Tree National Monument (J. E. Weir, Jr., g)
    - Kaweah-Tule area (M. G. Croft, g)
    - Kern River fan (R. H. Dale, g)
    - Kings River area (R. W. Page, g)
    - Lassen County, test-well sites, Bureau of Land Management (F. Kunkel, g)
    - Lava Beds (Whiskeytown Reservoir) (R. H. Dale, g)
    - Lompoc Plain (R. E. Evenson, g)
    - Lower Mojave area, west part (G. M. Hogenson, g)

Water resources—Continued
- California (Sacramento)—Continued
  - Ground water—Continued
    - Point Arguello (R. E. Evenson, g)
    - Santa Maria Valley (R. E. Evenson, g)
    - Summerland (R. E. Evenson, g)
    - Twentynine Palms Marine Corps Training Center (H. B. Dyer, g)
- Colorado (Denver):
  - Hydrology of Arkansas River basin—Canon City to State line (C. T. Jenkins, s)
  - Ground water:
    - Occurrence and development in State (J. A. McConaghy, g)
    - Summary of pumping tests in State (W. W. Wilson, g)
    - Trends in ground-water development of the Colorado High Plains (A. J. Boettcher, g)
    - Bent County (J. H. Irwin, g)
    - Big Sandy Valley below Limon (D. L. Coffin, g)
    - Cache La Poudre Valley (L. A. Hershey, g)
    - Denver Basin, ground-water trends (G. H. Chase, g)
    - Denver Basin (G. H. Chase, g)
    - Huerfano County (T. G. McLaughlin, g)
    - Kit Carson County (G. H. Chase, g)
    - Parts of Larimer, Logan, Morgan, Sedgwick, and Weld Counties (W. G. Weist, g)
    - North and Middle Parks (P. T. Voegeli, g)
    - Otero County and part of Crowley County (W. G. Weist, g)
    - Pueblo and Fremont Counties (H. E. McGovern, g)
    - Rocky Mountain Arsenal (M. C. Van Lewen, g)
    - Ute Mountain–Ute Indian Reservation (J. H. Irwin, g)
- Connecticut:
  - Water resources of Connecticut—Part 1, Quinebaug River basin (A. D. Randall, Jr., q, Albany, N.Y.)
  - Water resources of Connecticut—Part 2, Shetucket River basin (M. P. Thomas, s, Hartford)
  - Ground water, lower Quinnipiac and Mill River lowlands (A. M. LaSala, Jr., g, Hartford)
- Florida (g, Tallahassee; s, q, Ocala):
  - Alachua, Bradford, Clay, and Union Counties, water resources (W. E. Clark, g)
  - Broward County, water resources (C. B. Sherwood, g)
  - Econfina Creek basin area, water resources (R. H. Musgrove, s)
  - Escambia and Santa Rosa Counties, water resources (R. H. Musgrove, s)
  - Everglades National Park, water resources (J. H. Hartwell, s)
  - Green Swamp area, water resources (R. W. Pride, s)
  - Myakka River basin, water resources (B. F. Joyner, q)
  - Orange County, water resources (W. F. Lichter, g)
  - Ground water:
    - Cape Canaveral area, Brevard County, geohydrology (D. W. Brown, g)
    - Dade County, special studies (H. Klein, g)
    - Duval, Nassau, and Baker Counties (G. W. Leve, g)
    - Fort Lauderdale area, special studies (H. Klein, g)
    - Polk County (H. G. Stewart, g)
    - Pompano Beach area, north Broward County (G. R. Tarver, g)
    - Statewide, special studies (C. S. Conover, g)

Water resources—Continued
- Florida (g, Tallahassee; s, q, Ocala)—Continued
  - Ground water—Continued
    - Tampa Bay area (W. W. Wetterhall, g)
    - Venice well field, Sarasota County, geohydrology (W. E. Clark, g)
  - Surface water, St. Johns, Flagler, and Putnam Counties (W. E. Kenner, s)
- Georgia (Atlanta):
  - River-systems studies (A. N. Cameron, s)
  - Ground water:
    - Floyd and Polk Counties (C. W. Cressler, g)
    - Seminole, Decatur, and Grady Counties (C. W. Sever, g)
- Guam (Honolulu, Hawaii):
  - Ground water (D. A. Davis, g)
  - Surface water (S. H. Hoffard, s)
- Hawaii (Honolulu):
  - Ground-water storage and depletion, Molokai Irrigation Tunnel, Molokai (G. T. Hirashima, s)
  - Hydrologic studies (G. T. Hirashima, s)
  - Influence of water-development tunnels on streamflow–ground water relations, Oahu (G. T. Hirashima, s)
  - Water production from the Waiaha catchment area (S. S. Chinn, s)
  - Ground water:
    - Kahuku area, Oahu (K. J. Takasaki, g)
    - Kohala Mountain–Mauna Kea area (D. A. Davis, g)
    - Mokuleia–Waialua area, Oahu (J. C. Rosenau, g)
    - Waianae district, Oahu (C. P. Zones, g)
    - Windward Oahu (K. J. Takasaki, g)
- Idaho (Boise):
  - Little Lost River basin, water resources (H. A. Waite, g)
  - Ground water:
    - Aberdeen–Springfield area (H. G. Sisco, g)
    - American Falls (M. J. Mundorff, g)
    - Artesian City area (E. G. Crosthwaite, g)
    - Lower Teton Basin (E. G. Crosthwaite, g)
    - Mud Lake Basin (P. R. Stevens, g)
    - Salmon Falls Creek area (E. G. Crosthwaite, g)
    - Teton Basin (E. G. Crosthwaite, g)
    - Upper Star Valley (E. H. Walker, g)
- Indiana (Indianapolis):
  - Ground water:
    - Northwestern Indiana (J. S. Rosenshein, g)
    - West-central Indiana (F. A. Watkins, g)
- Iowa (Iowa City):
  - Water utilization and availability of central Iowa (F. W. Twenter, R. W. Coble, g)
  - Ground water:
    - Cerro Gordo County (W. L. Steinhilber, g)
    - Linn County (R. E. Hansen, g)
    - The Mississippian aquifer of Iowa (W. L. Steinhilber, g)
    - Water availability from glacial deposits of south-central Iowa (J. W. Cagle, g)
- Kansas (Lawrence):
  - Ground water:
    - Brown County (C. K. Bayne, g)
    - Butler County (J. M. McNellis, g)
    - Cherokee County (W. J. Seevers, g)
    - Decatur County (W. G. Hodson, g)

Water resources—Continued
- Kansas (Lawrence)—Continued
  - Ground water—Continued
    - Ellsworth County (W. Ives, g)
    - Finney, Kearny, and Hamilton Counties (W. R. Meyer, g)
    - Grant and Stanton Counties (S. W. Fader, g)
    - Johnson County (H. G. O'Connor, g)
    - Labette County (W. L. Jungmann, g)
    - Linn County (W. J. Seevers, g)
    - Miami County (D. M. Miller, g)
    - Montgomery County (H. G. O'Connor, g)
    - Morton County (L. C. Burton, g)
    - Neosho County (W. L. Jungmann, g)
    - Northwestern Kansas (W. R. Meyer, g)
    - Pratt County (C. W. Lane, g)
    - Republican River valley (S. W. Fader, g)
    - Rush County (J. McNellis, g)
    - Sedgwick County (C. W. Lane, g)
    - Southwestern Kansas (W. R. Meyer, g)
    - Trego County (W. G. Hodson, g)
    - Wallace County (W. G. Hodson, g)
    - Walnut River basin (J. M. McNellis, g)
- Kentucky (Louisville):
  - Lexington-Fayette County area, water resources (H. T. Hopkins, g)
  - Mammoth Cave area, water resources (R. V. Cushman, g)
  - Ground water:
    - Alluvial terraces of the Ohio River (W. E. Price, g)
    - Jackson Purchase area (L. M. MacCary, g)
    - Jenkins-Whitesburg area (D. S. Mull, g)
    - Louisville area (E. A. Bell, g)
- Louisiana (Baton Rouge):
  - Bossier and Caddo Parishes, water resources (H. G. May, g)
  - Rapides Parish, water resources (R. Newcome, Jr., g)
  - Vernon Parish, water resources (A. J. Calandro, s)
  - Water-supply characteristics of Louisiana streams (L. V. Page, s)
  - Ground water:
    - Baton Rouge-New Orleans valley area (G. T. Cardwell, g)
    - East and West Feliciana Parishes (C. O. Morgan, g)
    - Geismar-Burnside area (R. A. Long, g)
    - Greater New Orleans area (J. R. Rollo, g)
    - Southeastern Louisiana (M. D. Winner, g)
    - Southwestern Louisiana (A. H. Harder, g)
- Maine (Augusta):
  - Ground water:
    - Coastal area of southwestern Maine (G. C. Prescott, g)
    - Lower Penobscot basin (G. C. Prescott, g)
- Maryland (Baltimore):
  - Systems planning studies of the Gunpowder Falls basin (D. O'Bryan, w, W)
  - Ground water:
    - C and O Canal (E. G. Otton, g)
    - Charles County (T. H. Slaughter, g)
    - Prince Georges County (F. K. Mack, g)

Water resources—Continued
- Massachusetts (Boston):
  - Ground Water:
    - Assabet River basin (S. J. Pollock, g)
    - Brockton-Pembroke area (R. G. Petersen, g)
    - Cape Cod National Seashore (R. G. Peterson, g)
    - Central Boston area (W. N. Palmquist, g)
    - Ipswich River drainage basin (E. A. Sammel, g)
    - Lower Merrimack valley (E. A. Sammel, g)
    - Minute Man National Historical Park (R. G. Petersen, g)
    - Parker and Rowley River drainage basins (E. A. Sammel, g)
    - Shawsheen River basin (S. J. Pollock, g)
    - Southern Plymouth County (J. M. Weigle, g)
    - Western Massachusetts (O. M. Hackett, g)
    - Westfield River basin, (R. G. Petersen, g)
- Michigan (Lansing):
  - Marquette Iron Range, water resources (S. W. Wiitala, s)
  - Van Buren County, water resources (G. E. Hendrickson, g)
  - Ground water:
    - Alger County (K. E. Vanlier, g)
    - Battle Creek area (K. E. Vanlier, g)
    - Jordon River National Fish Hatchery (R. F. Brown,, g, St. Paul, Minn.)
    - Menominee County (K. E. Vanlier, g)
  - Surface water, North Branch Clinton River basin (S. W. Wiitala, s)
- Minnesota (St. Paul):
  - Hydrologic investigation of the Tamarac River basin, Marshall County (R. W. Maclay, g)
  - Water resources in the vicinity of municipalities in the Mesabi Range area (R. D. Cotter, g)
  - Ground water:
    - Aurora area (R. W. Maclay, g)
    - Grand Rapids area (E. L. Oakes, g)
    - Hibbing area (R. F. Norvitch, g)
    - Kittson, Marshall, and Roseau Counties (G. R. Schiner, g)
    - Melt-water channels near Marshall, Lyon County (G. L. Thompson, g)
    - Nett Lake area (R. F. Norvitch, g)
    - Nobles County and part of Jackson County (R. F. Norvitch, g)
- Mississippi (Jackson):
  - Water resources of Pascagoula River basin (E. J. Harvey, g)
  - Water-resources appraisals of a part of southwestern Mississippi (E. J. Harvey, g)
  - Ground water:
    - Geology and ground-water resources of Alcorn County (E. H. Boswell, g)
    - Geology and ground-water resources of Lauderdale County (J. W. Lang, E. H. Boswell, g)
    - Ground-water appraisals in northwestern Mississippi (B. E. Wasson, g)
    - Pearl River basin (B. E. Ellison, g)
- Montana (Billings):
  - Ground water:
    - Big Hole Battlefield National Monument (R. G. McMurtrey, g)

Water resources—Continued
- Montana (Billings)—Continued
  - Ground water—Continued
    - Bitterroot Valley, Ravalli County (R. G. McMurtrey, g)
    - Cedar Creek anticline, west flank (O. J. Taylor, g)
    - Deer Lodge Valley (R. L. Konizeski, g)
    - Fort Belknap Indian Reservation (D. C. Alverson, g)
    - Frazer-Wolf Point irrigation project (W, B. Hopkins, g)
    - Judith Basin, western part (E. A. Zimmerman, g)
    - Lower Bighorn River valley—Hardin Unit (L. J. Hamilton, g)
    - Milk River bottoms, Fort Belknap area (W. B. Hopkins, g)
    - Missoula Valley (R. G. McMurtrey, g)
    - Two Medicine irrigation project (Q. F. Paulson, g)
- Nebraska (Lincoln):
  - Ground water:
    - Fillmore County (C. F. Keech, g)
    - Hall County (C. F. Keech, g)
    - Mirage Flats (C. F. Keech, g)
    - Richardson County (P. A. Emery, g)
    - York County (C. F. Keech, g)
- Nevada (Carson City):
  - Hydrology of a portion of the Humboldt River valley (P. Cohen, w)
  - Ground water:
    - Amargosa Valley (T. E. Eakin, G. E. Walker, w)
    - Black Rock Desert (W. C. Sinclair, w)
    - Cave Valley (T. E. Eakin, w)
    - Dixie and Fairview Valleys (D. E. Everett, w)
    - Dry Lake and Delamar Valleys (T. E. Eakin, w)
    - Duck Valley (W. C. Sinclair, w)
    - Garden and Coal Valleys (T. E. Eakin, w)
    - Hualapai Flat (W. C. Sinclair, w)
    - Long Valley–Massacre Lake region (W. C. Sinclair, w)
    - Pahranagat and Pahroc Valleys (T. E. Eakin, w)
    - Pahrump Valley (G. T. Malmberg, w)
    - Pueblo Valley–Continental Lake area (W. C. Sinclair, w)
    - Reese River valley (E. G. Crosthwaite, w)
    - Sarcobatus Flat, Nye County (G. T. Malmberg, w)
    - Stonecabin and Ralston Valleys (T. E. Eakin, w)
- New Hampshire (Boston, Mass.):
  - Ground water, lower Merrimack River basin (J. M. Weigle, g)
- New Jersey (Trenton):
  - Summary of streamflow, 1955–60 (A. C. Lendo, s)
  - Water budget of Great Swamp (E. G. Miller, s)
  - Ground water:
    - Burlington County (F. E. Rush, g)
    - Camden County (E. Donsky, g)
    - Cumberland County (J. G. Rooney, g)
    - Essex County (J. Vecchioli, g)
    - Monmouth County (L. A. Jablonski, g)
    - Morris County (H. E. Gill, g)
    - Ocean County (H. R. Anderson, g)
    - Pine Barrens (E. C. Rhodehamel, g)
    - Rahway area (H. R. Anderson, g)
    - Salem County (J. C. Rosenau, g)

Water resources—Continued
- New Jersey (Trenton)—Continued
  - Ground water—Continued
    - Warren Grove area, geologic and hydrologic characteristics of the upper Tertiary deposits (F. E. Rush, g)
    - Water-level fluctuations in New Jersey, 1958–62 R. Austin, g)
    - Wharton Tract (E. C. Rhodehamel, g)
- New Mexico (Albuquerque):
  - Evaluation of pumping effects in the Malaga Bend area, Eddy County (E. R. Cox, g)
  - Evaluation of well-field data at Los Alamos (R. L. Cushman, g)
  - Hydrology of damsites on the Mescalero Apache Indian Reservation (J. S. Havens, g)
  - Hydrologic almanac of State (W. E. Hale, g)
  - Miscellaneous activities under the New Mexico State Engineer program (L. V. Davis, g)
  - Quantitative analysis of water resources in the Albuquerque area, Bernalillo County (H. O. Reeder, g)
  - Quantitative analysis of the ground-water system in the Roswell basin, Chaves and Eddy Counties (G. E. Maddox, g)
  - Water supply for Los Alamos (R. L. Cushman, g)
  - Ground water:
    - Gila Cliff Dwellings National Monument, Catron County, geology and ground-water resources (F. D. Trauger, g)
    - Grant County (F. D. Trauger, g)
    - Guadalupe County (A. Clebsch, Jr., g)
    - Lake McMillan and Carlsbad Springs, ground-water conditions between (E. R. Cox, g)
    - Luna County, southern (G. C. Doty, g)
    - McKinley County, southeastern (J. B. Cooper, g)
    - McMillan delta area (E. R. Cox, g)
    - Mesita, Laguna Indian Reservation, deep well test (G. A. Dinwiddie, g)
    - Quay County (W. A. Mourant, g)
    - San Juan County, northern (F. D. Trauger, g)
    - Sandia and Manzano Mountains area (F. B. Titus, g)
    - White Sands Integrated Range, northern (J. E. Weir, g)
    - White Sands Missile Range, reconnaissance, ground-water resources at selected sites (G. C. Doty, g)
    - White Sands Missile Range, test drilling (G. C. Doty, g)
    - White Sands Missile Range, test drilling at Apollo site (G. C. Doty, g)
- New York (Albany):
  - Lake Erie–Niagara area, water resources (A. L. La-Sala, g)
  - Ground water:
    - Ground water in New York (R. C. Heath, g)
    - Babylon-Islip area, Suffolk County (I. H. Kantrowitz, g)
    - Jamestown area (L. J. Crain, g)
    - Nassau County (N. M. Perlmutter, g)
    - Nassau County, northeast (J. Isbister, g)
    - Niagara Frontier (R. H. Johnston, g)
    - Orange and Ulster Counties (R. W. Robison, g)
    - Queens County (J. Soren, g)

Water resources—Continued
- New York (Albany)—Continued
  - Ground water—Continued
    - Rensselaer County, Schodack terrace (J. Joyce, g)
    - Schenectady County, eastern (J .D. Winslow, g)
    - Suffolk County, mid-island area (N. M. Perlmutter, g)
    - Syracuse area (I. H. Kantrowitz, g)
  - Surface water:
    - Babylon-Islip area (E. J. Pluhowski, s)
    - Gazetteer of streams (F. L. Robison, s)
    - Surface-water resources of New York (J. C. Kammerer, g)
- North Carolina (Raleigh):
  - Stream sanitation and water supply of State (G. C. Goddard, s)
  - Ground water:
    - Asheville area (P. M. Brown, g)
    - Cape Hatteras National Park, quality of ground water (H. B. Wilder, q)
    - Chowan County (P. M. Brown, g)
    - Craven County (P. M. Brown, g)
    - Durham area (P. M. Brown, g)
    - Hartford–Elizabeth City area (P. M. Brown, g)
    - Marion area (P. M. Brown, g)
    - Martin County (G. G. Wyrick, g)
    - Monroe area (E. O. Floyd, g)
    - Murphy area (P. M. Brown, g)
    - New Hanover County (G. Bain, g)
    - Northwestern North Carolina (P. M. Brown, g)
    - Raleigh area (J. O. Kimrey, g)
    - Southport area (P. M. Brown, g)
    - Waynesville area (P. M. Brown, g)
  - Surface water:
    - Interpretation of surface-water data (G. C. Goddard, s)
    - Neuse River headwaters, surface-water resources (G. C. Goddard, s)
- North Dakota (Grand Forks):
  - Ground water:
    - Barnes County (T. E. Kelly, g)
    - Burleigh County (P. G. Randich, g)
    - Cass County (R. L. Klausing, g)
    - Devils Lake area (Q. F. Paulson, g)
    - Divide County (C. A. Armstrong, g)
    - Foster and Eddy Counties (C. J. Huxel, Jr., g)
    - Richland County (Q. F. Paulson, g)
    - Stutsman County (C. J. Huxel, g)
    - Traill County (H. M. Jensen, g)
- Ohio (Columbus):
  - Hydrologic atlas (W. P. Cross, s)
  - Ground water:
    - Fairfield County (G. D. Dove, g)
    - Geauga County (J. Baker, g)
    - Miami River basin (A. M. Spieker, g)
    - Northeastern Ohio (J. L. Rau, g)
- Oklahoma (Oklahoma City):
  - Special investigations and reports (A. R. Leonard, g)
  - Thickness of the fresh ground-water zone (D. L. Hart, g)
  - Ground water:
    - Arkansas and Verdigris River valleys (H. H. Tanaka, g)

Water resources—Continued
- Oklahoma (Oklahoma City)—Continued
  - Ground water—Continued
    - Clinton-Sherman Air Force Base (A. R. Leonard, g)
    - Washita River valley near Anadarko, ground-water potential (D. L. Hart, Jr., g)
    - Woodward County (P. R. Wood, g)
  - Surface water:
    - Kiamichi River basin (L. L. Laine, s)
    - Little River basin (A. O. Westfall, s)
    - Muddy Boggy River basin (A. O. Westfall, s)
- Oregon (Portland):
  - Ground water:
    - Deschutes County, Tumalo-Sisters area (E. R. Hampton, g)
    - East Portland area (B. L. Foxworthy, g)
    - Eola-Amity Hills area, northern Willamette Valley (D. Price, g)
    - French Prairie area, northern Willamette Valley (D. Price, g)
    - Molalla-Salem slope area, northern Willamette Valley (E. R. Hampton, g)
- Pennsylvania (Harrisburg):
  - Ground water:
    - Brunswick Formation (S. M. Longwill, g)
    - Chester County, metamorphic and igneous rocks (C. W. Poth, g)
    - Lancaster County, carbonate rocks (H. Meisler, g)
    - Martinsburg Shale (L. D. Carswell, g)
    - New Oxford Formation (H. E. Johnston, g)
  - Swatara Creek basin, water resources (W. T. Stuart, g, W)
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