Geological Survey Research 1961

Synopsis of Geologic and Hydrologic Results

GEOLOGICAL SURVEY PROFESSIONAL PAPER 424-A

Geological Survey Research 1961

THOMAS B. NOLAN, *Director*

GEOLOGICAL SURVEY PROFESSIONAL PAPER 424

A synopsis of geologic and hydrologic results, accompanied by short papers in the geologic and hydrologic sciences. Published separately as chapters A, B, C, and D

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FOREWORD

The Geological Survey is engaged in many different kinds of investigations in the fields of geology and hydrology. These investigations may be grouped into several broad, interrelated categories as follows:

(a) Economic geology, including engineering geology
(b) Regional geologic mapping, including detailed mapping and stratigraphic studies
(c) Resource and topical studies
(d) Ground-water studies
(e) Surface-water studies
(f) Quality-of-water studies
(g) Field and laboratory research on geologic and hydrologic processes and principles.

The Geological Survey also carries on investigations in its fields of competence for other Federal agencies that do not have the required specialized staffs or scientific facilities.

Nearly all the Geological Survey's activities yield new data and principles of value in the development or application of the geologic and hydrologic sciences. The purpose of this report, which consists of 4 chapters, is to present as promptly as possible findings that have come to the fore during the fiscal year 1961—the 12 months ending June 30, 1961.

The present volume, chapter A, is a synopsis of the highlights of recent findings of scientific and economic interest. Some of these findings have been published or placed on open file during the year; some are presented in chapters B, C, and D; still others have not been published previously. Only part of the scientific and economic results developed during the year can be presented in this synopsis. Readers who wish more complete or more detailed information should consult the bibliography of reports beginning on page A–156 of this volume, and the collection of short articles presented in the companion chapters as follows:

Prof. Paper 424–B—Articles 1 to 146
Prof. Paper 424–C—Articles 147 to 292
Prof. Paper 424–D—Articles 293 to 435

A list of investigations in progress in the Geologic and Water Resources Divisions with the names and addresses of the project leaders is given on pages A–110 to A–155 for those interested in work in progress in various areas or on special topics.

During the fiscal year 1961, the services of the Geologic and Water Resources Divisions were utilized, or supported financially in part, by the many Federal and State agencies listed on pages A–106 to A–109. The Geological Survey has also cooperated from time to time with other agencies, and some of the work described in these chapters stems from work of previous years in cooperation with agencies not shown on the list. All cooperating agencies are identified where appropriate in the individual short articles in chapters B, C, and D, and they are mentioned in connection with some of the larger programs summarized in chapter A; because of space limitations, however, their contributions are mentioned in many of the short summary paragraphs contained in chapter A.

The many cooperating agencies, by means of financial support, technical cooperation, and friendly counsel, have contributed significantly to the findings reported in these chapters.

This report, which was prepared between March and July 1961, represents the combined efforts of many individuals. Paul Averitt assumed overall responsibility and assembled chapter A from information supplied by project chiefs and program leaders. Arthur B. Campbell and William J. Mapel critically reviewed most of the manuscripts submitted for chapters B, C, and D. They were assisted in this task by Stanley W. Lohman, Edward T. Ruppel, Paul K. Sims, and Vernon E. Swanson. Mrs. Virginia P. Byers helped check, process, and assemble the papers. R. A. Weeks and Charles J. Robinove compiled the lists of cooperating agencies and the list of investigations in progress. Barbara Hillier compiled the list of publications. Edith Becker and Marston Chase prepared the indexes to chapters B, C, and D. To these must be added the many contributors of articles, summaries and ideas. I am pleased to be able to acknowledge here the contributions and efforts of these individuals.

Thomas B. Nolan

THOMAS B. NOLAN,
Director.

Synopsis of Geologic and Hydrologic Results

Prepared by members of the Geologic and Water Resources Divisions

GEOLOGICAL SURVEY RESEARCH 1961

GEOLOGICAL SURVEY PROFESSIONAL PAPER 424-A

A summary of recent scientific and economic results, accompanied by a list of reports released in fiscal 1961 and a list of investigations in progress

UNITED STATES GOVERNMENT PRINTING OFFICE, WASHINGTON : 1961

UNITED STATES DEPARTMENT OF THE INTERIOR

STEWART L. UDALL, *Secretary*

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Thomas B. Nolan, *Director*

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GEOLOGICAL SURVEY RESEARCH, 1961

SYNOPSIS OF GEOLOGIC AND HYDROLOGIC RESULTS

RESOURCE INVESTIGATIONS

Resource investigations of the Geological Survey cover the broad fields of minerals, fuels, and water. Most of these investigations can be grouped into (a) district and regional studies and (b) commodity and topical studies.

The district and regional studies are concentrated in areas known or believed to contain mineral, fuel, or water resources of present or possible future value. These studies are intended to establish guides useful in the search for concealed deposits, to define areas favorable for exploration, and to appraise the resource potential. Most district and regional studies involve detailed geologic mapping, which adds to overall knowledge of the geology of the United States and contributes to the development of new general principles of wide application.

The commodity and topical studies are more varied. They include preparation on a national basis of estimates of total quantities of various resources, synthesis of data on habits of occurrence of individual resources that will help define environments favorable for study or exploration, and experimental and theoretical studies on the origin, composition, and distribution of such resources.

The long range objectives of both groups of studies are to determine the geologic environments in which individual commodities and mineral resources in general occur, and to develop valid theoretical principles and unifying concepts concerning their origin and occurrence. This information provides a foundation from which private industry can extend its search for useful raw materials, and it provides the Nation with a continuing inventory of its mineral wealth.

Important new findings in the fields of heavy metals, light metals, industrial minerals, radioactive materials, fuels, and water are summarized in the following pages.

HEAVY METALS

DISTRICT AND REGIONAL STUDIES

Montana iron deposits

Geologic mapping by H. L. James and K. L. Wier has shown that the Kelly iron deposit, Madison County, Mont., is a bed normally about 20 to 30 feet thick in Precambrian hornblende-diopside gneiss that is overlain by quartzite. At the nearby Carter Creek deposit, Beaverhead County, the iron formation is a bed normally about 40 feet thick in a sequence consisting mainly of dolomite marble and amphibolite. Locally, as in areas now being actively explored by private companies, the thickness of each bed of iron formation has been greatly increased as a result of squeezing or tight folding.

Chromite deposits of the Stillwater complex, Montana

E. D. Jackson, J. I. Dinnin, and Harry Bastron (1960) have shown that the Cr_2O_3 content of clean chromite from within the two minable chromitite zones of the Stillwater complex decreases upward, and that Cr/Fe values also decrease upward, generally 40 to 50 percent from bottom to top of a zone. Both the Cr_2O_3 content and Cr/Fe ratios are lower in olivine-bearing chromite layers than in adjacent massive chromitite layers. This information is essential to successful development of the deposits because the low-grade chromite in disseminated layers near the tops of ore zones cannot be raised to commercial grade by milling.

Nickeliferous lateritic soils in the Klamath Mountains, Oregon and California

Field studies by P. E. Hotz (Art. 404)[1] have confirmed that several deposits of nickeliferous red soil in northwest California and southwest Oregon have been formed by weathering of peridotite. The deposits are relatively thin and of small areal extent, and hence are submarginal as nickel ore. However, a deposit at Nickel Mountain, Douglas County, Oreg., is currently being mined.

Tungsten and molybdenum in the Rocky Mountains

Widespread occurrence of molybdenum-bearing scheelite and powellite of Precambrian age in Colorado and part of Wyoming, principally in calc-silicate members of gneissic terrains, has been described by Ogden Tweto (1960). Minor concentrations of tungsten originally present in the Precambrian sedimentary

[1] Article 404 in Professional Paper 424–D. All references to articles in chapters B, C, and D are given in this style. Articles 1–146 are in chapter B; articles 147–292 are in chapter C; and articles 293–435 are in chapter D.

rocks were redistributed and recrystallized through successive Precambrian plutonic episodes. The deposits found thus far are of minor economic importance, but some are still being found and others probably exist. The Precambrian tungsten may have a bearing on the occurrence of the Tertiary deposits, which have been important sources of tungsten in Colorado.

Through participation in the Defense Minerals Exploration Administration project in cooperation with the Molybdenum Corporation of America, at Questa, N. Mex., R. U. King, E. N. Harshman, and J. W. Hasler contributed to the discovery of a major potential source of molybdenum. In November 1960, the company announced that the project had disclosed about 260 million tons of rock containing approximately 5 pounds of MoS_2 per ton, equivalent to 760 million pounds of molybdenum metal.

Manganese and zinc deposits near Philipsburg, Montana

Pyrolusite, cryptomelane, todorokite, chalcophanite, hetaerolite, manganite, and a manganese mineral that resembles synthetic gamma- and rho-MnO_2 have been identified by W. C. Prinz (Art. 127) in the manganese deposits near Philipsburg, Mont. The two zinc-bearing oxides—chalcophanite and hetaerolite—occur only as alteration products of primary rhodochrosite associated with sphalerite. They may, therefore, prove useful as guides to deeper ores of this kind.

Studies in Colorado

Studies by E. T. McKnight in the Rico district, Colorado, have shown that many of the lead-zinc deposits are on the fringes of massive pyritic "blanket veins" that extend along limestone beds outward from their intersections with mineralizing fractures. The fractures themselves are obscure and displace the beds only slightly.

A significant contribution to the problem of zoning of sulfide mineral deposits has been made by P. K. Sims (1960b) and Paul B. Barton, Jr., (Barton, Toulmin, and Sims, 1960) in their studies in the Central City district, Colorado. The district-wide pattern is interpreted as having originated from cooling of solutions from initial temperatures of about 600° C to about 200° C as they moved upward and outward. As reflected by systematic changes in the composition of sphalerite, the chemical potential of sulfur dropped slowly during cooling and the more sulfur-rich mineral assemblages were deposited peripherally. Presumably, the chemical potential of sulfur changed through homogeneous reactions in the ore fluid, for there is no indication of extensive reaction with wall rock at this stage.

Base and precious metals were deposited in part concurrently with the widespread propylitic alteration throughout and beyond the Silverton caldera, northwestern San Juan Mountains, Colo. The paragenesis of ore and gangue minerals, and the structural evolution of veins and chimneys in the district as determined by W. S. Burbank and R. G. Luedke (Art. 149), indicate that two kinds of primitive ore solutions were involved, one of which was richer in sulfur compounds than the other. The observed differences in mineral assemblages and in paragenesis are due to mixing of these solutions with solutions containing end products of rock alteration and with oxygenated meteoric waters.

In much of the Leadville area, Colorado, the bedrock is deeply buried beneath unconsolidated deposits. Studies of these deposits and related late Cenozoic events by Ogden Tweto (Art. 56) have shown that the bedrock surface is very irregular as a result of repeated canyon cutting by streams and glaciers, and of repeated movements on young faults. The rough topography of the bedrock—not previously recognized—accounts for the pattern of some ore deposits, and also affected the pattern of oxidation of the ores.

East Tintic silver-lead district, Utah

Continued exploration by the Bear Creek Mining Company has extended the known limits of the Burgin ore body, which was discovered through application of principles developed by Survey personnel, as described by T. S. Lovering and H. T. Morris (1960). The extension of the buried thrust fault zone in which the deposit lies is being traced as part of a new program of surface and subsurface exploration. The success of this venture has stimulated new exploration to the southeast by the Tintic Utah Mining Company.

Central mining district, New Mexico

A complex history of intrusions, domal uplift, subsidence, volcanic activity, renewed intrusion, and faulting between Late Cretaceous and early Miocene time has been worked out in the Central mining district, New Mexico, by W. R. Jones, R. M. Hernon, and W. P. Pratt (Art. 150). About 30 varieties of intrusive rocks in the district can be assigned to four age groups within this time interval, and the youngest group can itself be divided into five subgroups on the basis of cross-cutting relationships. After the first group of intrusions had domed Upper Cretaceous and older sediments, differential subsidence led to formation of the Santa Rita horst. Some volcanism and additional faulting followed a period of erosion, and then three discordant plutons were forcibly injected; these plutons in turn were cut by the earliest dikes of the youngest intrusive group before any significant mineralization occurred. Extensive ore deposits of several types formed in carbonate sedimentary rocks, the intrusive rocks, and along major faults before dikes of the second subgroup were injected. Early Miocene volcanic rocks around the edges of the horst provide an upper time limit to the events described.

Lead, zinc, and related ores of the Central and Eastern States

Several independent but related studies have contributed new data on the origin of Mississippi Valley-type ores. W. S. West and Harry Klemic (Art. 296) present evidence that in the Belmont and Calamine quadrangles, Wisconsin, solution-thinning of limestone beds by meteoric waters initiated slumping and brecciation that prepared the sites for later mineralization. The ore-depositing solutions probably were of nonmeteoric origin.

Helmuth Wedow is applying high-speed computer techniques to data from drill holes in the eastern Tennessee zinc district to test the correlation between occurrence of sphalerite and variation in thickness of limestone units, which are believed to be thinned locally by solution. As records for more than 1 million feet of drilling are available, successful adaptation of computer methods to this problem will greatly reduce the labor involved and may point the way to application of this technique elsewhere.

In the Mascot-Jefferson City area, Tennessee, the zinc deposits are apparently localized by major structural features rather than by features related to thinning. A. L. Brokaw (1960) points out that the deposits are restricted to a zone of elongate domes and bent folds that lies transverse to the regional trend of Appalachian folds and overthrusts.

A. V. Heyl, Jr., and M. R. Brock (Art. 294) relate the fluorspar-zinc deposits of the Kentucky-Illinois district to doming and fractures at the intersection of two major fault zones. One of these is the zone of strong shears that connects the Central Kentucky, Kentucky-Illinois and Southeast Missouri districts. An explosion breccia at Hicks Dome in the northern part of the Kentucky-Illinois district has been dated as Cretaceous on the basis of an age determination made by T. E. Stern on a thorium-rich monazite specimen taken from the mineralized breccia. The monazite is of a type which, according to W. C. Overstreet, is characteristic of extremely deep-seated intrusions.

Work by W. E. Hall and Irving Friedman on stable isotopes in fluid inclusions in ores from the Kentucky-Illinois and Wisconsin districts suggests that the mineralizing solutions in the two districts changed in the same way during the course of ore deposition. Highly concentrated deuterium-rich brines in early minerals give way to less concentrated and relatively deuterium-poor fluids in younger ore and gangue minerals. The change in chemistry and isotopic composition of the fluids in the inclusions is believed to be due to mixing of waters of different origins. (See p. A–96.)

Gold in California

Mapping by J. P. Albers and others (Art. 147) in the French Gulch-Deadwood gold mining district in northern California, done in cooperation with the California Division of Mines, has shown that the lodes are quartz veins along steep faults in the Bragdon formation and along a thrust contact between the Bragdon and underlying Copley greenstone. Seven mines along an east-west zone 9 miles long and less than a mile wide have yielded most of the 835,000 ounces of gold thus far obtained from the district.

COMMODITY STUDIES

In a review of gold-producing districts in the United States, A. H. Koschmann and M. H. Bergendahl (1961) have found that there are 504 districts in which total gold production has exceeded 10,000 ounces. Gold production in the United States reached an all-time high of 4,869,949 ounces in 1940. Since then it has declined to less than half this figure. Reserves are sufficient to support production at the rate of 1940, but marked changes in the economics of gold mining would be necessary to achieve such an output.

Germanium has in the past been recovered mainly as a byproduct of zinc smelters. New analyses and a review of the literature by Michael Fleischer (Art. 110) show that copper sulfides, especially enargite, commonly contain higher concentrations of germanium than does sphalerite. The possibility of recovering germanium commercially from byproducts of certain copper smelters warrants attention.

TOPICAL STUDIES

Heavy metals and trace elements in black shales and phosphorites

Samples collected by D. F. Davidson and H. W. Lakin (Art. 267) from six selected shale units in the western United States contain metal in amounts comparable to those of shale units considered "ore" in other parts of the world. The samples are from the so-called "vanadiferous shale" in the Permian Phosphoria formation of western Wyoming and southeastern Idaho; the Comus formation of Ordovician age, near Golconda, Nev.; an unnamed lower Paleozoic formation in the Fish Creek range, near Eureka, Nev.; the Mississippian Deseret limestone at Mercur Dome, near Tintic, Utah; the Chainman shale of Mississippian age near Ely, Nev.; and the Pennsylvanian Minnelusa formation in the southern Black Hills, S. Dak. All the shale units are black, and all are rich in organic material. They contain as much as 1.5 percent zinc, 5 percent vanadium, 1 to 2 percent nickel, 0.7 percent selenium, and lesser amounts of other metals.

Similarly, J. D. Love (Art. 250) has found that the Meade Peak phosphatic shale member of the Phosphoria formation near Afton, Wyo., contains as much as 2.5 percent V_2O_5, 1.3 percent ZnO, 1 percent TiO_2, 0.5 percent Cr_2O_3, 0.3 percent NiO, 0.1 percent MoO_3, and 0.068 percent Se. A 3-foot bed averages 0.9 percent V_2O_5 and contains 45 million tons of rock to a depth of 500 feet below the level of major streams.

Analyses by R. A. Gulbrandsen (1960a, b) of 60 samples of phosphorites from the Phosphoria formation show the following approximate modal and maximum contents, respectively, of minor elements: Cr, 0.1 and 0.3 percent; La, Ni, Sr, V, Y, 0.03 and 0.1 percent; Ba, Cd, Cu, Mn, Mo, Nd, Zn, 0.01 and 0.03 percent; As, U, 0.005 and 0.02 percent; B, Zr, 0.003 and 0.01 percent; Se, 0.001 and 0.007 percent; Ag, Co, Pb, Sb, Sc, Yb, 0.001 and 0.003 percent; Ga, <0.001 and 0.001 percent; Be, 0.00005 and 0.0003 percent. He finds that the high chromium phosphorites are likely to contain greater than average amounts of other minor elements and organic matter. He also finds that Sr, U, and the rare earths are enriched in the apatite component of the rock, whereas Ag, Zn, V, Cr, Mo, As, Sb, and Se are enriched in the organic component.

LIGHT METALS AND INDUSTRIAL MINERALS

DISTRICT AND REGIONAL STUDIES

Beryllium at Spor Mountain, Utah

In mineralogic studies of beryllium ore from Spor Mountain, Utah, E. J. Young and W. R. Griffitts have found that bertrandite is the main ore mineral and that associated introduced minerals are fluorite, opal (β-cristobalite), montmorillonite, and quartz. The ore is very fine grained and many of the bertrandite particles are smaller than one micron, which may make beneficiation difficult. The distribution of beryllium in nodules and hand specimens of the Spor Mountain ore was determined by means of a contact printing method devised by W. R. Griffitts and L. E. Patten (Art. 286).

Beryllium in the Mount Wheeler area, White Pine County, Nevada

Work in the Mount Wheeler area, Nevada, by D. H. Whitebread and D. E. Lee (Art. 193) has shown that the so-called Wheeler limestone contains beryllium minerals in an area 1 mile north of the Mount Wheeler mine as well as at the mine itself. This limestone unit, which is within 70 feet of the base of the Pioche shale, of Cambrian age, may be either a single continuous bed or a series of lenses. The beryllium minerals at the mine and at the new occurrences are associated with quartz veinlets that cut the limestone. The new occurrences are near a quartz monzonite stock that is the inferred source of the beryllium. Veinlets of quartz in the so-called Wheeler limestone probably will serve as the most useful guide in further search for beryllium minerals in this area.

Beryllium in the Lake George district, Colorado

Beryllium deposits in the Lake George district, Colorado, described previously by Hawley, Sharp and Griffitts,[2] and by Sharp and Hawley[3] are associated with pink biotite granite related to the Pikes Peak granite of the Colorado Front Range. The largest known deposit, at the Boomer mine, is closely associated with a small granite stock that was intruded into schist, gneiss, and pegmatite. Other such deposits may yet be found in association with obscure or buried stocks in the part of the area consisting mainly of metamorphic rocks. Possible surface guides to such stocks are concentrations of aplitic dikes, rocks altered to quartz-muscovite-fluorite greisen, and large premineralization faults that appear to have guided emplacement of granites.

Beryllium deposits in the areas of metamorphic rocks contain visible crystals of beryl; deposits in the granites contain inconspicuous bertrandite with or without beryl. The beryllium-bearing mineral euclase has been found in small amounts at the Boomer and Redskin mines, and may occur other places in the area in minor amounts. This seems to be the first discovery of euclase in North America.

Pegmatites of the Spruce Pine district, North Carolina

F. G. Lesure infers that deformed minerals and gneissic or cataclastic structures that are common in pegmatites of the Spruce Pine district may be the result of synorogenic emplacement of the pegmatites, and that the late faulting and shearing may have formed during movement of the Blue Ridge thrust sheet (Bryant and Reed, 1960).

Vermiculite deposits in South Carolina

W. C. Overstreet and Henry Bell have found that the zircon-rich vermiculite deposits of the South Carolina Piedmont are altered parts of the wall zones of syenite pegmatite dikes. These wall zones are as much

[2] Hawley, C. C., Sharp, W. N., and Griffitts, W. R., 1960, Premineralization faulting in the Lake George area, Park County, Colorado, *in* Short papers in the geological sciences: U.S. Geol. Survey Prof. Paper 400–B, p. B71–B73.

[3] Sharp, W. N., and Hawley, C. C., 1960, Bertrandite-bearing greisen, a new beryllium ore in the Lake George district, Colorado, *in* Short papers in the geological sciences: U.S. Geol. Survey Prof. Paper 400–B, p. B73–B74.

as 20 feet thick. The vermiculite is a product of the alteration of biotite, which is an abundant primary constituent of the pegmatite.

The biotite and vermiculite are commonly in pegmatites that cut gabbro or amphibolite, but also occur where the dikes cut felsic rocks. Thus it seems certain that composition of the wall rock is not as important in the origin of vermiculite deposits as was previously supposed.

Fluorspar in the Browns Canyon district, Salida, Colorado

In a cooperative project with the Colorado State Metal Mining Fund, R. E. Van Alstine has mapped the geology of the Poncha Springs NE quadrangle, Colorado, which covers the main part of the Browns Canyon fluorspar district in Chaffee County. The fluorspar deposits occur chiefly along steep northwest-trending normal faults in Tertiary volcanic rocks and Precambrian granite and gneiss. The volcanic rocks are older than lower Pliocene sediments. One of the faults is at least 3.5 miles long and contains ore almost continuously for about 2,600 feet. The maximum thickness of the fissure veins is about 40 feet, and the CaF_2 content ranges from about 25 to 75 percent. The ore consists principally of fine-grained fluorite and quartz, mutually interspersed or interlayered. Minor constituents include calcite, barite, pyrite, marcasite, opal, montmorillonite, kaolin, a stilbite-like zeolite, manganese oxides (cryptomelane, pyrolusite, and manganite), hematite, and limonite. The wall rocks have been altered locally, either by the introduction of fluorite and silica, or by the development of chlorite or clay minerals.

Phosphate deposits in the Southeastern States

During the course of a detailed study of the phosphate deposits in the land-pebble district of Florida, J. B. Cathcart has found an explanation for the northern and eastern limits of phosphate occurrence. Primary phosphate in the land-pebble district occurs in the Hawthorn formation of middle Miocene age. The minable deposits, however, are in residuum at the top of the Hawthorn formation and in the lower part of the overlying Bone Valley formation, of Pliocene age. The reworking and concentration of weathered and disintegrated phosphatic material took place in a sea that reached its northern limit on the flank of a hitherto undescribed positive structural element, called the Hillsborough high, which is related to the much larger Ocala uplift. The Hillsborough high was rising as the Hawthorn formation was being deposited, and it remained as a positive area during the early part of the Pliocene. There are no minable phosphate deposits north of the high. The eastern margin of the district is a sharp line at the edge of a ridge that acted as a barrier to the sea during deposition of the lower part of the Bone Valley formation. The lower unit does not extend east of this ridge, and, accordingly, economic phosphate deposits do not occur there.

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J. B. Cathcart and F. W. Osterwald have concluded that all economic phosphate deposits in the Southeastern States are similar to the Florida deposits in origin and in tectonic setting, although they occur in rocks of Ordovician and Pennsylvanian ages, in addition to rocks of Tertiary age. They are all derived mainly by the weathering and reworking of sandy and clayey phosphatic limestone beds that were deposited on the rising flanks of foreland domes, far from the sources of clastic material. The phosphate was deposited in a rather narrow depth zone, and as the domes rose, phosphatic limestone was deposited at a progressively greater distance from the crest of these structures. Limestone beds of equivalent age but in a different tectonic setting are not phosphatic.

Clay in Maryland

Bloating clays from Maryland, described previously by M. M. Knechtel and J. W. Hosterman,[4] have been subjected to rotary-kiln firing tests by H. P. Hamlin of the U.S. Bureau of Mines. These clays were sampled during an investigation conducted in cooperation with the Maryland Department of Geology, Mines, and Water Resources, and with the U.S. Bureau of Mines. The material tested came from exposures of the St. Marys formation, of Miocene age, at three localities along the shore of Chesapeake Bay in Calvert County, Md. The tests indicate that the clay in each of these places is suitable for the manufacture of expanded lightweight aggregate. Enough of this bloating clay may be available in southern Maryland, and perhaps also in other parts of the Atlantic Coastal Plain, to supply a new industry.

Clay in Kentucky

In a cooperative study with the Kentucky Geological Survey, J. W. Hosterman and S. H. Patterson (Art. 120) have found that refractory clay of the Lower Pennsylvanian Olive Hill clay bed is exposed in a belt approximately 15 miles wide that extends southwesterly 55 miles from the Ohio River near Portsmouth, Ohio, to Frenchburg, Ky., and may extend 50 miles farther south to Laurel County, Ky. Boehmite, a bauxite mineral identified recently by X-ray, occurs locally as nodules in the clay. Previously, bauxite minerals had not been known in the Olive Hill clay

[4] Knechtel, M. M., and Hosterman, J. W., 1960, Bloating clay in Miocene strata of Maryland, New Jersey, and Virginia, *in* Short papers in the geological sciences: U.S. Geol. Survey Prof. Paper 400–B, p. B59–B62.

bed, although they are common in the Lower Pennsylvanian Mercer clay of central Pennsylvania.

Borate in California

During the course of an investigation of the Furnace Creek borate area, carried on in cooperation with the California Division of Mines, J. F. McAllister has found that weathering at the surface of the borate deposits tends to produce minerals relatively high in B_2O_3. Some of these minerals have not been described previously, and others are exceedingly rare. One of the new minerals is nobleite ($CaO \cdot 3B_2O_3 \cdot 4H_2O$), described by R. C. Erd, J. F. McAllister, and A. C. Vlisidis. McAllister (Art. 129) has identified sborgite ($Na_2O \cdot 5B_2O_3 \cdot 10H_2O$), reported otherwise only from Italy; and Erd and others (Art. 255) have identified tunellite ($SrO \cdot 3B_2O_3 \cdot 4H_2O$), found previously only at Boron, Calif. The sborgite was found in an efflorescence of thenardite and halite on outcrops of somewhat saline lake beds in the Furnace Creek formation. Sborgite forms in the present environment, as demonstrated by a few stalactites of sborgite, thenardite, and some halite, in a mine.

Pumice and pozzolan deposits in the Lesser Antilles

Very large deposits of pumiceous material are now known to occur on the Caribbean islands of Dominica, Martinique, and St. Eustatius. As described by E. B. Eckel (1960b), the deposits contain both lump pumice, which is used chiefly for lightweight building blocks, and fine-grained pumicite, which has excellent pozzolanic properties. The deposits are within easy shipping distance of many potential markets in Puerto Rico and elsewhere in the Caribbean, as well as along the east and gulf coasts of the United States. They could provide the basis of an important local industry.

COMMODITY AND TOPICAL STUDIES

Beryllium

W. R. Griffitts and E. F. Cooley (Art. 109) have investigated the beryllium content of cordierite, which is structurally similar to beryl and therefore might be expected (in places) to contain noteworthy amounts of beryllium. Specimens of cordierite from pegmatite and from quartz veins in pegmatite districts contained a maximum of 0.2 percent Be, which is high for a nominally nonberyllian mineral but far lower than that of beryl.

Research is continuing in an effort to improve and extend instrumental techniques in which the gamma-neutron reaction is used to detect beryllium. A drill-hole logger using this principle has been successfully field tested by W. W. Vaughn and associates.

Potash

Three classes of potash deposits have been recognized by C. L. Jones during the course of studies in New Mexico: (a) widespread polyhalite deposits formed by replacement of anhydrite beds; (b) sylvite and langbeinite, associated with other potassium, magnesium, and sodium salts, formed in halite beds; and (c) small monomineralic lenses and veins of sylvite, polyhalite, and carnallite that cut various rocks. Of the three types of deposits, only the second has been mined.

Stratigraphic and petrographic studies of evaporite deposits in the Paradox Basin, Utah, by R. J. Hite (Art. 337), in addition to the work in New Mexico, indicate that deposition of the evaporites and associated sediments was cyclic, or even doubly cyclic. Deposition under regressive conditions is recorded by the downward sequence of halite-anhydrite-carbonate, and under transgressive conditions by the reverse of this sequence. Deposition in probable response to seasonal variations in the salinity of the water is recorded by thick units of finely laminated, varvelike rocks. Reorganization of materials since deposition has greatly complicated the original relations.

RADIOACTIVE MATERIALS

DISTRICT AND REGIONAL STUDIES

Colorado Plateau

Botryoidal coffinite in a specimen from the Woodrow mine near Laguna, N. Mex., has been observed by R. H. Moench to be interbanded with pyrite, cobaltite, and barite and to contain small amounts of galena, wurtzite, cobaltite, and a trace of chalcopyrite. These textural relations suggest that the uranium and sulfide minerals were formed at the same time.

From study of uranium-vanadium and copper deposits in the Lisbon Valley area of Utah and Colorado, G. W. Weir and W. P. Puffett (1960c) have concluded that the two kinds of deposits were formed by the same or similar low-temperature hypogene solutions, because: (a) copper minerals occur in many uranium-vanadium deposits, (b) uranium and vanadium minerals occur in some copper deposits, (c) both kinds of deposits occur in tabular bodies in sedimentary rocks, and (d) the copper deposits are near faults.

Because regional variations of Mo, As, Co, Ni, Zn, and Se in uranium deposits in the Salt Wash member of the Morrison formation correspond with differences in tuff content of the member, A. T. Miesch (Art. 123) concludes that these elements were derived from the tuffaceous component of the member and collected into deposits by solute diffusion. Another group of elements, Cu, Ag, much of the Pb, V, U, and some Zn came from external sources and were introduced later by solution flow.

Although all samples of identifiable fossil wood from several uranium deposits in the Colorado Plateau region are species of araucarian conifers, the uranium content differs so markedly among samples of one species from a single deposit that R. A. Scott (Art. 55) concludes that the kind of wood in the deposits was not an important control in localizing ore.

Shirley basin, Wyoming

E. N. Harshman (Art. 148) has found that the major uranium deposits in the Shirley basin, Wyo., lie just west of a northwesterly trending ridge on the pre-Tertiary erosion surface upon which the ore-bearing Wind River formation accumulated. In Wind River time, streams transporting arkosic debris from granitic areas lying to the southwest were diverted parallel to the ridge. Resultant physical and chemical conditions were favorable for the subsequent concentration of uranium in deposits parallel to and west of the ridge.

Coastal plain, Texas

Relatively recent discovery of hydrogen sulfide-bearing oil and gas in fields adjacent to faults and down dip from uranium deposits in Karnes and adjoining counties, Texas, has led D. H. Eargle and A. D. Weeks (Art. 295) to postulate that hydrogen sulfide seeping from those sources into overlying Tertiary rocks may have created reducing environments in which uranium was precipitated from alkaline ground water.

Front Range, Colorado

In study of primary black uranium ores in the Front Range, Colo., P. K. Sims, E. J. Young, and W. N. Sharp (Art. 2) have found that coffinite, previously thought to be rare in uranium vein deposits of the United States, is present in 6 veins of epithermal type and is an important ore mineral in at least 3 of these.

Powderhorn district, Colorado

In the Powderhorn district, Gunnison County, Colo., D. C. Hedlund and J. C. Olson (Art. 121) have found that thorium, niobium, and rare earths are concentrated in (a) veins bearing thorite and thorogummite, (b) dikes and plug-like bodies of carbonatite, where they are contained in pyrochlore, monazite, apatite, bastnaesite, and synchisite, (c) segregations of magnetite-ilmenite-perovskite, and (d) trachyte dikes.

TOPICAL STUDIES

Epigenetic deposits of uranium in limestone

Data on uranium deposits in northwestern New Mexico compiled by L. S. Hilpert (Art. 3) indicate that deposits in limestone are always of epigenetic origin; they occur in rocks of Permian and Triassic age deformed by faulting, or in rock of Jurassic age (Todilto limestone) deformed by intraformational folding; and they are distributed in two different geologic provinces, the Colorado Plateau and the Basin and Range. Because these deposits and others described in the geologic literature occur under rather diverse geologic conditions, he concludes that carbonate rocks are good hosts for epigenetic uranium deposits only where these rocks are deformed.

Geology of uranium deposits in sandstone

Review and analysis by W. I. Finch of the large amount of data on uranium deposits in sandstone indicate that about 98 percent of the pene-concordant deposits are in sandstone formed in continental sedimentary environments. The sandstone accumulated in closed or partly closed basins—mainly in areas bordering the stable interior platforms, and to a minor extent in postorogenic depressions, including some fault-block valleys. None of the sandstone accumulated in geosynclines. Uranium-bearing lignite, some uranium-bearing limestone, and uranium-bearing conglomerate of Precambrian age had a similar sedimentary and tectonic setting. Continental rocks formed in such environments offer the best opportunities for finding new uranium-bearing deposits.

Source of monazite in some Australian placers

In reviewing the literature concerning the geology of monazite, W. C. Overstreet finds that detrital monazite on beaches fronting the South Pacific in Queensland and New South Wales contains 6.6 ± 0.5 percent thoria (ThO_2) as compared to only one-tenth to one-fifth that amount in monazite from stream placers in the tin fields of the highlands upstream from the coast. This marked difference suggests that monazite of the beaches cannot, as previously thought, have come from the same source rocks as that in the stream placers. The composition of the monazite on the beaches suggests that it was derived from plutonic gneiss bodies not now exposed.

FUELS

PETROLEUM AND NATURAL GAS

Many studies carried on within the Survey contribute fundamental stratigraphic and geologic data that are used by those engaged in petroleum exploration. These studies are reported under regional headings, beginning on page A-9.

COAL

Coal studies by the U.S. Geological Survey include (a) geologic mapping and stratigraphic studies of specific coal fields; (b) appraisal of resources in individual coal fields, States, or the whole nation; and (c) investigation of the petrography, composition, and structure of coal.

Coal fields of the United States

A new map of the coal fields of conterminous United States by James Trumbull (1959) shows, on a scale of 1: 5,000,000, the distribution of coal-bearing areas, in colors according to the rank of coal. Inset maps and diagrams show geologic ages of coal-bearing rocks, the basis of coal-rank determination, bituminous coal producing districts, cumulative coal production to January 1, 1959, and estimated original coal reserves, by States.

Coal resources of Arkansas

In a report prepared in cooperation with the Arkansas Geological and Conservation Commission, B. R. Haley (1960) estimates that the original reserves of low-volatile bituminous coal and semianthracite in Arkansas totaled 2,272 million tons. This estimate is 70 percent larger than that made by M. R. Campbell in 1908.

Geology of specific coal fields

Studies by W. C. Warren (1959) in the Birney-Broadus coal field in Rosebud and Powder River Counties, Mont., have shown that the field contains about 21.5 billion tons of subbituminous coal in beds 2½ or more feet thick and within about 1,000 feet of the surface.

Geologic investigations in the Livingston-Trail Creek coal field, Montana, by A. E. Roberts indicate that the field contains 226 million tons of coal. Analyses of 89 coal samples from the field indicate that the coal is of high-volatile bituminous rank.

Spheroidal structures in coal

Coal beds in the Vermejo formation of Cretaceous age and in the Raton formation of Cretaceous and Paleocene age in the Trinidad coal field, Colorado, exhibit two types of spheroidal structure. R. B. Johnson (Art. 153) believes that one type is the result of stresses due either to lateral movements or shrinkage during lithification; the other type seems to be the result of shrinkage caused by heat from nearby sills.

OIL SHALE

Studies of the oil shale in the Green River formation of Eocene age in the southeastern Uinta basin, Utah, by W. B. Cashion (Art. 154) indicate that an area of 690 square miles is underlain by an oil-shale sequence 15 to 370 feet thick. The sequence will yield about 15 gallons of oil per ton of rock and the potential oil reserves of the area total about 53 billion barrels.

Mapping by W. C. Culbertson in the Firehole basin 15-minute quadrangle, Wyoming, has demonstrated that a sequence 40 feet thick in the upper part of the Tipton shale member of the Green River formation is a persistent oil-rich unit underlying at least 500 square miles in and near the quadrangle. Assays of cores and outcrop samples indicate that the unit will yield 18 to 30 gallons of oil per ton of shale and that it contains at least 20 billion barrels of oil.

WATER

REGIONAL AND DISTRICT STUDIES

Distribution and characteristics of streamflow

The amount and variation of surface-water supplies in the United States is ascertained by means of a network of about 7,200 continuous-record stream-gaging stations. Of these about 2,800 are primary stations at which streamflow data are recorded continuously for long periods. About 1,400 are secondary stations that are operated for periods of 5 to 10 years and are moved from place to place as required. The remaining 3,000 stations serve miscellaneous needs for streamflow data. In addition, special information on low- or high-flow characteristics is obtained at about 5,000 partial-record station.

Data from this network of stations are summarized and analyzed in areal studies of the availability of water supplies. For example, a study of water supplies of Kanawha County, W. Va., by W. L. Doll, B. M. Wilmoth, Jr., and G. W. Whetstone (1960) resulted in the conclusion, based on the present rate of increase in water use, that enough water is available in the Kanawha River basin to supply needs for many years to come.

In Puerto Rico, Ted Arnow and J. W. Crooks (1960) found that of 93 million gallons per day delivered to 76 urban and 860 rural areas, about 90 percent of the production was from surface-water sources.

R. W. Pride and J. W. Crooks have concluded from a study of rainfall and streamflow records in Florida that the drought of 1954-56 was the most severe on record. In this 3-year period, deficiencies in annual rainfall ranged from 7 to 11 inches; and the average annual runoff from the State was only about 6 inches, as compared to the long-term average runoff of about 14 inches.

Records of streamflow in Kansas analyzed by L. W. Furness (1960), show that, in general, the low flows decrease progressively westward except that in the Marais des Cygnes basin they are lower than regional values and in parts of south-central Kansas they are higher. On most streams in the western part of the State and in parts of the Marais des Cygnes and Neosho basins the discharge diminishes to zero every other year on the average. On the South Fork Ninnescah River basin, where the flow is sustained better than elsewhere in Kansas, the annual minimum 7-day flow is as much as 0.06 cubic feet per second per square mile at average intervals of 2 years.

Man's activities may have a profound effect on streamflow. In a study of the effects of reforestation in four small areas in New York, W. J. Schneider and G. B. Ayer (1961) found through examination of streamflow records collected since 1952 that reforestation had resulted in significant decreases in runoff. At the time of the study three of the areas had been partly (35 to 58 percent) reforested, mostly with species of pine and spruce. As a result, runoff from one stream was reduced 0.36 inch per hydrologic year and peak discharges during the dormant season were reduced by an average of 41 percent. Significant change in peak flows during the growing season could not be demonstrated.

In a study of the effects of urbanization, A. O. Waananen (Art. 275) concludes that peak rates of runoff from areas of urban development may be 3 to 4 times greater than those from nearby undeveloped areas.

WATER USE

Water use in river basins of Southeastern United States

The river basins of Southeastern United States cover an area of 86,543 square miles in parts of South Carolina, Georgia, Florida, and Alabama. Withdrawal of water in these basins totaled nearly 3,900 mgd (million gallons per day) during 1960 according to a study by K. A. MacKichan and J. C. Kammerer (1961). This amount is equivalent to 750 gallons per capita per day. The withdrawal was divided among several classes of users as follows: industry, 3,300 mgd; public supplies, 400 mgd; rural domestic and livestock, 110 mgd; and irrigation, 42 mgd. Of the total withdrawn, only 290 mgd was consumed. Water use by the Savannah River plant of the Atomic Energy Commission is not included. About 61 percent of the surface water and 94 percent of the ground water was withdrawn in the Coastal Plain part of the basins. The total withdrawal increased 31 percent between 1955 and 1960. Consumptive use probably increased at about the same rate. The use of saline water was almost three times as great in 1960 as in 1955.

Copper industry

About 330 mgd of water was used in 1955 in mining and manufacturing primary copper. About 70 percent was used in mining and concentrating ore and about 30 percent was used to reduce the concentrate to primary copper. About 60 mgd, or 18 percent, of the water was used consumptively, and nearly all of the consumptive use occurred in the water-short areas of the West. On the average about 50 gallons of water is required to produce a pound of refined copper.

Much of the water used in producing primary copper was of low quality. About 46 percent contained 1,000 ppm (parts per million) or more of dissolved solids. Median total dissolved solids in water used in mining and ore concentration average a little less than 400 ppm, and hardness (as $CaCO_3$) a little more than 200 ppm. The corresponding median values for water used in smelting and refining average only half these amounts.

Styrene, butadiene, and synthetic rubber industries

The water requirements of the styrene, butadiene, and synthetic rubber industries totaled about 710 mgd in 1959, according to an analysis by C. N. Durfor. The intake of the individual industries was as follows: butadiene, 429 mgd; styrene, 158 mgd; special-purpose rubber, 94 mgd; and SBR (styrene-butadiene rubber), 29 mgd. The butadiene industry consumed 4.5 percent of its intake, the styrene industry, 2.0 percent, the special-purpose rubber industry, 9.1 percent, and the SBR industry, 11 percent.

Most of the water intake was used for cooling: butadiene, 96 percent; styrene, 98 percent; special-purpose rubber, 90 percent; and SBR, 17 percent. Of the total intake, 64 percent of the water was salty. These waters, which were used only for once-through cooling, contained as much as 35,000 ppm of dissolved solids. Excluding these salty waters the maximum hardness of the intake water used for the production of butadiene was 342 ppm; for styrene, 404 ppm; for SBR, 495 ppm; and for special-purpose synthetic rubber, 618 ppm.

REGIONAL GEOLOGY AND HYDROLOGY

In addition to the resource investigations described on the preceding pages, the Geological Survey is engaged in studies of broader scope aimed at an understanding of the geology and hydrology of the United States.

Studies of the composition, structure, history, and origin of the rocks that compose the earth's crust in the United States are carried out by regional geologic mapping, together with parallel studies in the fields of geophysics, geochemistry, stratigraphy, and paleontology. The preparation of general-purpose geologic maps and accompanying studies often provide the first clue to the location of new mineral districts, and they aid directly in the search for concealed deposits. They also provide background information for (a) appraising the potential mineral, fuel, and water resources of various parts of the country, (b) selecting favorable sites for engineering works such as highways, dams, de-

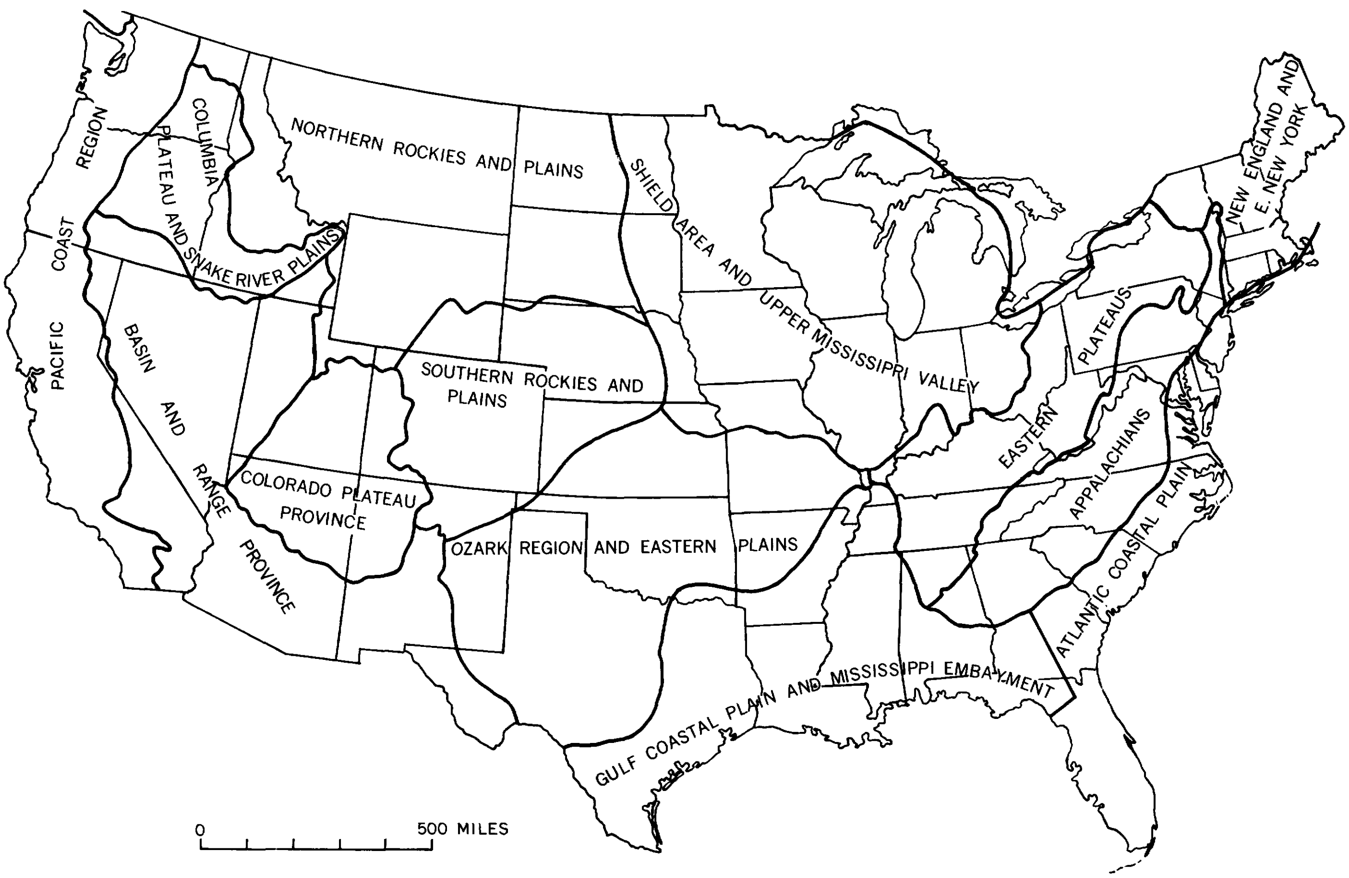

FIGURE 1.—Index map of conterminous United States showing boundaries of regions referred to on accompanying pages.

fense tests, and homes, and (c) enhancing appreciation of scenic features and recreational areas.

Studies of the quantity, quality, and availability of the Nation's water resources are carried out in part through areal investigations of districts and drainage basins. In these studies hydrologic and related geologic variables are examined and recorded. These variables include sources of inflow, the movements of surface and ground water, the effects of various geologic materials on water movements and on composition, the effects of water movements on rocks and sediments, and the disposition of water, including consumption, evaporation, transpiration, and outflow of both surface and ground waters. Such studies provide the basic data needed for an intelligent appraisal of the Nation's water resources; they make it possible to predict the effects of man's activities on water regimen, and they aid in solving local water problems.

Some of the major results of regional geologic and hydrologic work during the fiscal year 1961 are described in the following pages. These results are classified by region as shown in part on figure 1.

SYNTHESIS OF GEOLOGIC DATA ON MAPS OF LARGE REGIONS

The preparation of maps of national or larger scope is a minor but very important function of the Geological Survey. In compiling such maps the Survey depends largely on data gathered as part of local and regional mapping programs, supplemented by data generously provided by State surveys, private companies, and universities. The Survey also collaborates with national and international scientific societies in preparing, and sometimes publishing, maps of this type. Maps published or completed during the year are described under separate headings below. Collaborative maps in progress include:

1. Geologic map of North America, scale 1:5,000,000. This map, which is nearly completed, is being compiled by a committee of the Geological Society of America, E. N. Goddard, University of Michigan, chairman.
2. Basement rock map of North America from 20° to 60° N. latitude, scale 1:5,000,000. This map has been compiled by a committee of the American Associa-

tion of Petroleum Geologists, P. T. Flawn, University of Texas, Bureau of Economic Geology, chairman.

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. Woollard, University of Wisconsin, chairman.
4. Tectonic map of North America. This map, being compiled under the direction of P. B. King, is being prepared for the Subcommission for the Tectonic Map of the World, International Geological Congress.

Mineral distribution maps

Mineral distribution maps of conterminous United States are being compiled under the direction of P. W. Guild, T. P. Thayer, and W. L. Newman.

Occurrences of 22 mineral commodities throughout the 48 conterminous States are shown on a series of maps completed thus far. About half of the commodities are heavy metals and the remainder are light metals, industrial minerals, or radioactive materials. Maps of about 12 additional commodities are in various stages of preparation. The original maps are on transparent film on a scale of 1:2,500,000, designed as overlays for the geologic and tectonic maps of conterminous United States. They will be published on paper at a scale of 1:3,168,000, accompanied by short texts, locality indexes, and bibliographic references. Through cooperation of agencies of the Canadian and Mexican governments the series of distribution maps will include mineral occurrences throughout North America as part of the general program of the Subcommission for the Metallogenic Map of the World, International Geological Congress.

Tectonic map of the United States

A new tectonic map of the conterminous United States, on a scale of 1:2,500,000, will be released during the coming fiscal year. The map, prepared as a joint undertaking of the American Association of Petroleum Geologists and the Geological Survey under the direction of G. V. Cohee, is a complete revision of the tectonic map published by the Association in 1944.

By providing a geologic framework for delineating old and recognizing new mineral provinces, the tectonic map is of special value in the search for petroleum, natural gas, and ore deposits. The map also has great scientific value as a tool in the interpretation of the structural history of the United States.

Paleotectonic maps of the Permian system

The long-term program to produce paleotectonic map folios of national scope for each of the geologic systems is continuing. The folio for the Permian system, largely completed in 1960, is being readied for publication; work has been started on a folio for the Pennsylvanian system.

Interpretive maps prepared for each of several major subdivisions of the Permian system show the development of major tectonic elements in much of the central part of the continent.

Tectonism was still active very early in Permian time, following the intensive activity in many areas near the end of the Pennsylvanian period. Numerous basins of deposition (some topographically deep) were separated from adjacent basins by highlands, which contributed detritus to the basins. The longest landmasses, including the ancestral Rocky Mountains and the central Nevada ridge, trended northeasterly, but many shorter landmasses, such as the ancestral Wichita-Arbuckle and Uncompahgre uplifts, were alined northwesterly. Many small positive areas formed hills projecting above areas of deposition.

Relative tectonic stability characterized the second subdivision of the Permian system, composed largely of rocks of Leonard age. Many of the earlier positive areas had been reduced by erosion and buried by sediments. Widespread regional sinking or a eustatic rise of sea level resulted in the accumulation of widespread blankets of sediments in basins of deposition that were far more extensive than those in very early Permian time. Noteworthy changes also included the development of a marine connection in Wyoming between the Cordilleran geosyncline and the northern Midcontinent region, and in Arizona between the Cordilleran and the Sonoran geosynclines.

The central part of the continent in the latter part of Permian time was even more stable. Positive areas in the northern part of the Western Interior were further reduced in size and prominence, and deposition was more widespread. In the Southwest, however, an extensive area in Arizona and western New Mexico was emergent, although probably not very high. The supply of detritus in most of the Midcontinent region exceeded the amount that could be accommodated by regional downwarping, so many of the Permian basins were filled.

Pleistocene lakes in western conterminous United States

A new map of the western conterminous United States, prepared by J. H. Feth (Art. 47), shows the maximum known or inferred extent of Pleistocene lakes. Comparison of this map with reported lacustrine deposits of Oligocene, Miocene, and Pliocene ages suggests that the general area of occurrence of the Pleistocene lakes was a little west and southwest of the area of occurrence of the older lakes.

NEW ENGLAND AND EASTERN NEW YORK

Geologic mapping, geophysical and geochemical surveys, and water resources investigations in New England and eastern New York are carried on largely through cooperative agreements with the various States. Some of the results of this work are summarized below. The results of geochemical exploration in New England are described on page A–95.

Regional geologic mapping in Maine

Preliminary studies by Andrew Griscom on the petrology of a mafic intrusive complex in the Stratton quadrangle show that the lower, layered half of the intrusion contains about 12,000 feet of interlayered norite, anorthosite (with rare spinel), pyroxenite, and dunite, and that the upper, nonlayered portion grades upward from norite into biotite diorite.

E. V. Post has tentatively correlated rocks in The Forks quadrangle with lithologically similar rocks in the Stratton quadrangle, and in the Second Lake quadrangle, New Hampshire-Maine. The latter correlation, in turn, suggests a correlation with the "Arnold River Complex" of Ordovician age in Quebec.

The "ribbon rock" (a limestone with layers of slate) that underlies much of eastern Aroostook County was generally believed to be of Silurian age, but graptolites recently discovered by Louis Pavlides date it as Middle Ordovician (Trenton). Fossiliferous tuff from the Shin Pond area studied by R. B. Neuman has yielded brachiopods, trilobites, bryozoans, gastropods, and echinoderms of probable Early Ordovician (Arenig) age. Many of the species are new and the assemblage as a whole has European affinities. Neuman and W. B. N. Berry have recognized the European aspect of faunas in rocks that span a considerable part of the Ordovician in this region.

As the result of recent geologic mapping in west-central Maine and northern New Hampshire, A. L. Albee (Art. 168) suggests that the Taconic orogeny in this area involved major deformation and metamorphism rather than just a tilting of the older rocks.

Regional geologic mapping in Vermont

The tectonic fabric of north-central Vermont has been analyzed by W. M. Cady as the first phase of a study of orogenic movements. The B-axis elements of an earlier fabric approach a right angle to the B-axes of the folds of the later Green Mountain north-northeast trending anticlinorium.

Regional geologic mapping in Massachusetts and Rhode Island

R. F. Novotny (Art. 311) has identified a major unconformity as the base of the Pennsylvanian Worcester formation in east-central Massachusetts. The underlying strata may be Silurian, as suggested by stratigraphic continuity with units in Maine and New Hampshire. A major fault marked by silicified and brecciated zones has been mapped for a distance of 25 miles in east-central Massachusetts and southern New Hampshire and may continue southward to the vicinity of the Worcester "coal" mine.

Recent mapping in the Concord quadrangle by N. P. Cuppels (Art. 310) has revealed a northeast-trending fault zone at least 25 miles long. The fault zone crosses the southeastern part of the quadrangle, is younger than the Andover granite of Carboniferous age, and may be genetically related to the Northern Boundary fault of the Boston basin.

A striking example of frost-wedged bedrock has been discovered by Carl Koteff (Art. 170) at a locality north of New Bedford, in southeastern Massachusetts during mapping of the Assawompset Pond quadrangle. A knob of porphyritic granite that protrudes about 25 feet above the surrounding glacial deposits contains openings as much as 3 feet wide and 10 feet deep, developed along major joints. The joint blocks have been moved laterally over a gently dipping joint plane by frost wedging, presumably in a periglacial climate.

Marine sediments as much as 50 feet above present sea level are of late glacial age, according to work by R. N. Oldale (Art. 171) in the Salem quadrangle along the northeast coast of Massachusetts. The sediments were deposited when glacial ice stood nearby, as proglacial outwash is interbedded with and in part overlies the marine sediments. Sand dunes as much as 50 feet high and 8,400 feet long have been mapped in the Springfield South quadrangle by Joseph H. Hartshorn. The dunes are both bow-shaped and longitudinal. Their bedding dips consistently 7 to 12 degrees south, indicating winds primarily from the north, although the forms of some bow-shaped dunes indicate a component from the northwest.

Regional geologic mapping in Connecticut

A narrow stratigraphic zone in the granitic gneiss of southeastern Connecticut is characterized by keilhauite, an aluminum-, iron-, and rare-earth-bearing variety of sphene, according to Richard Goldsmith, G. L. Snyder, and Nancy M. Conklin (Art. 399). Keilhauite also occurs in rocks in Rhode Island now called the Scituate granite gneiss, and may be a useful stratigraphic marker in the gneisses of southern New England.

According to Richard Goldsmith (Art. 169), a distinctive aegerine-augite granite and associated rocks identify refolded isoclinal folds in the granitic gneisses and high-grade metasedimentary and metavolcanic rocks of southeastern Connecticut. The Hunts Brook syncline, an isoclinal syncline near New London, has been tightly refolded, possibly as a result of deformation that produced the generally westward-trending low-angle Honey Hill fault.

G. L. Snyder has recognized three periods of metamorphism in the rocks of the Norwich and Fitchville quadrangles: (a) regional dynamo-thermal metamorphism, either as a single continuous process or as a series of episodes between 530 and 280 million years ago; (b) dynamic metamorphism, progressively more localized along certain zones of active faulting; and (c) alteration or retrograde metamorphism that resulted in the hydration of sillimanite-containing schists.

The Waterbury gneiss has been divided by C. E. Fritts into two main metasedimentary units and at least two felsic metaigneous units. These rocks form the core of a dome. A thinly banded kyanite-bearing paragneiss that occurs east of Waterbury, Conn., contains as much as 54 percent kyanite and averages 9 percent, as judged from analyses of 29 samples.

A large recessional moraine about 8 miles north of Long Island Sound near New London has been identified by Richard Goldsmith (1960a) and named the Ledyard moraine. The moraine extends east-northeastward discontinuously for at least 13 miles, and marks a temporary halt in the retreat of ice from the moraines of Long Island and southern Rhode Island. A similar moraine found by R. B. Colton farther north near Windsorville, marks another previously unrecognized stand of the retreating ice.

Geophysical surveys

Gravity measurements by M. F. Kane in west-central Maine have delineated areas of mafic and felsic intrusive rocks in a dominantly sedimentary terrain. Detailed gravity profiles over exposed or near-surface intrusive bodies have given considerable information on their size and shape. Both gravity anomalies and density measurements show that the sedimentary rocks are, in general, intermediate in density between the mafic and felsic rocks.

In the Island Falls quadrangle, Maine, electromagnetic techniques have been used by F. C. Frischknecht and E. B. Ekren to map the bedrock below a concealing cover of glacial drift. In the northwest and central parts of the quadrangle, zones of conductive black slate are common in the sequence of concealed rock, which is of probable Cambrian and Ordovician ages. These slate zones can be distinguished electromagnetically from younger volcanic rocks in the northwest part of the quadrangle. In the central part the conductive zones occur in relatively narrow belts that are continuous for many miles. The conductive zones converge northeastward.

Pronounced magnetic highs over the five ring dikes or stocks of the White Mountain plutonic-volcanic series in New Hampshire have been found by R. S. Bromery. Samples of the ring-dike rocks are being examined by Andrew Griscom and the data used to determine the structure of the ring complexes. Within the ring-dike area, the Moat volcanics and the Littleton formation (schist and gneiss) are magnetically low. Aeromagnetic data show that the Conway granite within the ring-dike area is magnetically high, but that the Conway granite of the White Mountain batholith is magnetically low.

Seismic work on Block Island, Rhode Island, by C. R. Tuttle and W. B. Allen (Art. 240) indicates that a low-velocity zone of Pleistocene deposits is underlain successively by unconsolidated deposits, semiconsolidated deposits, and, at 1,088 feet below sea level, by crystalline rocks. The unconsolidated deposits are probably of Cretaceous age, the semiconsolidated deposits of Cretaceous or Triassic(?) age, and the crystalline rocks of Paleozoic age or older.

A study by Anna Jespersen of the results of an aeromagnetic survey of the Greenwood Lake and Sloatsburg quadrangles, New York-New Jersey, indicates that the steepest magnetic gradients and the highest magnetic susceptibilities are associated with Precambrian metasedimentary amphibolite and pyroxene amphibolite, the principal host rocks of the magnetite deposits in the Sterling Lake, N.Y.-Ringwood, N.J., area. The next two lower orders of magnetic susceptibility seem to be associated with quartz-oligoclase gneiss and hornblende granite, respectively.

Economic studies

Slate that has been quarried at about 25 places in the Greenville and Sebac Lake quadrangles, Maine, occurs in a sequence of interbedded dark-gray slate, siltstone, and fine-grained sandstone of probably Early Devonian age, according to geologic mapping by G. H. Espenshade (Art. 152). Slaty cleavage is well developed only where sandstone is interbedded with the slate. A large sample of slate with very poor cleavage was processed in the rotary kiln by the Bureau of Mines, and yielded lightweight aggregate of good quality from which satisfactory lightweight concrete was made.

A new copper vein at the upper contact of greenstone with schist of the Ottauquechee formation, exposed in roadcuts of the Waterbury Interchange on the new interstate highway to Montpelier, Vt., was sampled by L. R. Page and assayed 3 percent copper over a width of 44 inches.

Precambrian magnetite deposits, interpreted by B. F. Leonard and A. F. Buddington as high-temperature replacements of skarn and microcline granite gneiss, are confined to a structural knot in granitic terrain near the border of the Adirondacks massif (Art. 35). Magnetite in granite gneiss is locally accompanied by hypogene crystalline hematite and martite, and large deposits average about 25 percent recoverable iron.

Geochemical studies in New Hampshire

Chemical analyses of uranium and thorium in the Highlandcroft (Taconic), Oliverian (Acadian), and New Hampshire (Acadian) plutonic series of New Hampshire confirm that radioactivity is higher in the more felsic rocks of these series. In addition, according to J. B. Lyons (Art. 32), the much lower thorium-uranium ratios for pegmatites, contrasted with aplites, suggests that these coarse-grained rocks were formed by different processes of fractionation.

Aquifers composed of glacial deposits

During the course of recent studies in southeastern Massachusetts C. E. Shaw, Jr., and R. G. Petersen (1960) have concluded that the ground-water reservoir formed by stratified glacial drift along the Mattapoisett River is in hydraulic continuity with the stream and that the summer and autumn low flows of the Mattapoisett River are a measure of the minimum amount of water that can be developed on a sustained basis.

In a study of pumping tests on wells in twelve ground-water reservoirs in glacial outwash in Rhode Island, S. M. Lang, W. H. Bierschenk, and W. B. Allen (1960) found that coefficients of transmissibility ranged from 19,000 to 350,000 gpd (gallons per day) per foot, coefficients of permeability from 820 to 5,800 gpd per square foot, and coefficients of storage from 0.0008 to 0.20. Although outwash deposits are generally productive, the wide range in permeability indicates a considerable variation in productivity from one reservoir to another and from place to place within any one reservoir. The wide range in coefficients of storage indicates a spread between water-table and substantially confined conditions. The average transmissibility and permeability observed in the 12 reservoirs studied are higher than for much of the outwash because many of the wells tested had been located and constructed after the sites had been explored by test drilling.

Occurrence of water in bedrock

Further insight into the occurrence and movement of ground water in consolidated rocks has been obtained by F. W. Trainer and R. C. Heath (Art. 315) from an area in the St. Lawrence River valley in northeastern New York. The most permeable zones in the Beekmantown dolomite of this area are thin strata that contain moderately abundant cross fractures. These thin strata are separated by thick beds in which cross fractures are widely spaced. One of these thin zones, lying nearly horizontal, apparently acts as a pipe that conducts water southward from Canada beneath the St. Lawrence River and Lake St. Lawrence to discharge areas along the Grass and Raquette Rivers in the United States.

Chemical and physical quality of surface and ground water

In a study of the quality of water in major drainage basins of Connecticut and extreme southeastern New York, F. H. Pauszek (1960) has observed that (a) dissolved solids in surface water range from 26 to 216 ppm (parts per million), and the water is in general relatively soft, (b) water from streams in the Thames drainage basin is the softest—the observed range being only 10 to 33 ppm of hardness calculated as $CaCO_3$, (c) in the upper Housatonic drainage basin, some streams that drain terrains underlain by limestone and dolomite are high in dissolved solids, and a preponderance of calcium and magnesium makes the water somewhat harder, and (d) in all basins the water locally may be high in iron. The composition of the ground water in these basins is generally comparable to that of the streams, but has a greater range in amounts of dissolved solids.

Sediment discharge by Scantic Brook, a tributary of the Connecticut River, was less than 10 tons per day about 50 percent of the time. During the hurricane floods of 1955, however, 10,890 tons passed the Broad Brook station during the two days August 19 and 20. This was 70 percent of the total load for the year.

Unusually high concentrations of chloride and sodium ions in water generally from deeper parts of the bedrock in the vicinity of Massena, N.Y., are attributed by R. C. Heath and E. H. Salvas (Art. 251) to sea water that entered the rocks from the Champlain Sea, which covered the area 4,500 to 7,000 years ago. The sea water has been diluted but is not yet completely flushed out.

Flood magnitudes

Mean annual floods are lower in streams flowing from the northerly slopes of the Adirondack Mountains than elsewhere in New York State. Snow constitutes nearly half the yearly precipitation, lasts from early fall to late spring, and releases moisture slowly. The ratios of the 10-, 25-, and 50-year floods to the mean annual floods are also the lowest in the State. In contrast, streams in the southeastern part of New York, which also have small mean annual floods, have relatively high ratios for 25- and 50-year floods. These infrequent large floods are caused by hurricanes and coastal storms.

APPALACHIANS

Geologic studies and mapping are in progress in many parts of the Appalachian region, and water resources investigations are in progress in cooperation with State agencies in every State in the region. In addition to the results reported below, information on mineral deposits in the region is given on pages A–3 and A–4 to A–5; information on the Watchung lava flows in New Jersey on page A–77; and information on the trace element content of soils and plants at Canandaigua, N.Y., and in Washington County, Md., on pages A–94 to A–95.

Geologic mapping

Detailed quadrangle mapping by Bruce Bryant and J. C. Reed, Jr., (1960) has definitely established that the fault on the southeast side of the Grandfather Mountain window, North Carolina, is continuous with the fault that bounds the window on the north and west. Reconnaissance by Bryant and Reed (Art. 316) has demonstrated that the quartzite of the Stokes County area, North Carolina, resembles that of the Chilhowee group in the Grandfather Mountain window, rather than quartzite of the Kings Mountain belt with which it had been tentatively correlated. Structural relations of the Stokes County area suggest that it also may be a window.

Reconnaissance by J. C. Reed, Jr., H. S. Johnson, Jr., Bruce Bryant, Henry Bell III, and W. C. Overstreet in the Brevard schist belt of the Carolinas and northern Georgia has shown that the schist of this area is similar to the retrogressively metamorphosed rocks of the Table Rock quadrangle, previously mapped by Reed, and that the Brevard belt marks a major fault, as suggested earlier by Anna I. Jonas.

Overstreet and others (Art. 45) have recognized two major unconformities in the metasedimentary rocks of the South Carolina Piedmont. These unconformities can be correlated between the Kings Mountain belt and the Carolina slate belt. Lead-alpha age determinations on zircon crystals from plutonic rocks that intrude the rocks above and below these unconformities fall into three groups, thereby establishing that the unconformities were formed between Cambrian and Ordovician time and between Ordovician and Devonian time.

An interesting byproduct of geologic mapping in the slate belt of North Carolina was the discovery by A. M. White and A. A. Stromquist (Art. 118) of an anomalous suite of heavy minerals in small tributary streams of the Yadkin River in the High Rock quadrangle that probably were derived from remnant upland deposits laid down by the ancestral Yadkin River.

Reconnaissance mapping by R. M. Hernon in northwestern North Carolina has yielded good evidence, including relict amygdules, shape of the mass, and chemical composition, that the hornblende gneiss of that area was derived mainly from basalt flows.

J. P. Minard (Art. 172) has mapped two belts of previously unrecognized end moraines that extend across Kittatinny Mountain, Sussex County, N.J. The moraines and associated eskers form part of a discontinuous belt across the northern part of the State. They contain large amounts of sand and gravel suitable for use in construction, and locally are important ground-water reservoirs.

Structural and tectonic studies

P. B. King (Art. 41) has noted that mafic dikes of Triassic age trend northwestward in the segment of the Appalachians from Alabama to North Carolina, northward in the Virginia segment, and northeastward in the segment from Pennsylvania to New England. This pattern suggests the orientation of crustal stresses that existed in the Appalachian region during Triassic time.

New insight into the structural history of the Mascot-Jefferson City zinc district, Tennessee, is provided by a structure contour map prepared by J. G. Bumgarner, P. K. Houston, J. E. Ricketts and Helmuth Wedow, Jr. The contours, drawn on the Rocky Valley thrust surface and on several stratigraphic horizons in the West New Market area, reveal that after the main thrusting, late deformation along fold axes affected both the stationary and thrust blocks as a unit and folded the thrust surface.

L. D. Harris and Isidore Zietz have concluded from detailed mapping and aeromagnetic data that the structural development of the Cumberland overthrust block began with major folding that involved the basement rocks.

R. W. Johnson, Jr., (1960b) has shown from interpretation of aeromagnetic and gravity data over a wide area in eastern Kentucky and Tennessee that structural trends in the basement are only locally coincident with those of Appalachian origin exposed at the present surface. The general lack of coincidence strongly suggests that the basement rocks beneath the Cumberland Plateau (and probably also those beneath the Ridge and Valley province) have their own structural fabric of pre-Appalachian origin, a fabric that bears little if any direct relation to the overlying Appalachian structures.

Aeromagnetic profiles in the vicinity of the Clark Hollow peridotite intrusion, Union County, Tenn., compared by R. W. Johnson, Jr., (1961) with computed anomalies for various selected models indicate that the intrusive body is a nearly vertical or northwest-dipping elliptical cylinder. Previously the body had been inferred from surface evidence to be a tabular or lens-shaped mass along the southeast-dipping Wallen Valley fault. Structures within the plug suggest that it was emplaced before the period of thrusting and that its proximity to the Wallen Valley fault is coincidental.

Geologic mapping and structural studies in the vicinity of the Southern and Western Middle anthracite coal fields by J. P. Trexler, G. H. Wood, Jr., and H. H. Arndt (Art. 38), show that a previously unrecognized low- to high-angle unconformity separates rocks of the Catskill and Pocono formations in the western part of the Anthracite region. The rocks below the unconformity include the red-bed sequence at the top of the Catskill, the upper part of which contains a sparse flora of Early Mississippian age. These rocks were folded and partly truncated before the basal conglomerate of the Pocono was deposited. The unconformity at the base of the Pocono formation provides the first structural evidence that the Acadian orogeny affected the rocks of the Ridge and Valley province in eastern Pennsylvania.

T. A. Simpson (Art. 43) has observed that systems of open fractures associated with tight folds and major faults determine the direction of ground-water movement in the red-ore mines of the Birmingham district. The distinctive parallelism of the northeasterly-trending folds and faults in the Birmingham district suggests that both resulted from pressure from the southeast. Studies of the joint systems and their relation to the folds and faults also revealed a second stress-field caused by north-south compression.

Stratigraphic studies in the Ridge and Valley province

The upper part of the Knox dolomite in Smyth County, Va., is closely similar to the upper part of the dolomite in the zinc district of eastern Tennessee, as shown by detailed studies by R. S. Young and Helmuth Wedow, Jr. Moreover, in both areas the zinc and barite deposits occur in the first major limestone unit below the unconformity at the top of the Knox.

Geophysical study in the Maryland Piedmont

In the Rockville quadrangle, Maryland, Andrew Griscom and D. L. Peterson (Art. 388) found that the shape, size, and trend of bodies of mafic rock beneath thick saprolite could be mapped by means of combined aeromagnetic, aeroradioactivity, and gravity data.

Streamflow

The marked influence of environmental factors on hydrology is illustrated by two recently completed studies in Tennessee. C. T. Jenkins (1960a) found that in Tennessee the mean annual flood is related to drainage area by the equation $Q_{2.33}=CA^{0.77}$, in which $Q_{2.33}$ is by definition the mean annual flood having a 2.33-year recurrence interval, A is the drainage area, and C is a coefficient representing the influence of many physiographic, meteorologic, and other factors on the relation between area and the mean annual flood. Throughout the Blue Ridge and in the southeastern part of the Ridge and Valley province, C averaged 110. In the northern part of the Ridge and Valley province, it averaged 94. In spite of the greater precipitation along the mountain ridges and the precipitous terrain of the BlueRidge, these C values are significantly lower than the values of 145 and 170 reported for the Eastern Plateau region to the west. W. R. Eaton (1960) related annual 3-day minimum discharge to recurrence interval on a number of streams throughout Tennessee and found that streams have generally higher rates of base flow in the Applalachian region than elsewhere in Tennessee.

The average low-flow yields of streams in the portion of the Appalachian region within North Carolina and southern Virginia were found by G. C. Goddard, Jr., to be as much as eight times greater than in the eastern part of the Atlantic Coastal Plain. These results are based on the annual seven-day minium flow having an average recurrence interval of ten years. The average low-flow yields of several streams in southwestern North Carolina were 0.8 cubic feet per second per square mile, whereas the low-flow yields of many streams in the Atlantic Coastal Plain approached zero.

Sediment yield

Within the Appalachian region, J. W. Wark has found significant differences in computed annual sediment yield between streams in the Ridge and Valley province and in the Piedmont Plateau. In the Ridge and Valley province, annual sediment yields are about 100 tons per square mile. In the Piedmont province the yields are 200 or more tons per square mile. In urban areas such as Washington, D.C., the yields are as high as 1,000 tons per square mile.

ATLANTIC COASTAL PLAIN

Recent work on the Atlantic Coastal Plain has included geochemical and petrographic investigations, geologic mapping, and hydrologic studies as summarized below. Information on phosphate and clay deposits is given on page A–5, information on paleontological work is given on pages A–59 to A–61, and information on the rate of erosion on Martha's Vineyard on pages A–89 to A–90.

Geochemical and petrographic investigation in Florida

An earlier finding that extensive kaolinite deposits originate as a subaerial weathering product of montmorillonite in the Bone Valley formation of Florida has been documented by Z. S. Altschuler by means of X-ray, chemical, and electron microscope studies. The alteration proceeds by acid leaching of Na, K, Ca, Si, and P from the montmorillonite and associated marine apatite, and the clay is transformed to kaolinite without going through an intermediate phase. The coextensive, very widespread Citronelle formation of peninsular Florida is also dominantly kaolinitic and markedly weathered. Because the Citronelle and the Bone Valley formations have many features in common, it is likely that the kaolinite in the Citronelle is also of epigenetic origin.

Geologic mapping

Detailed field mapping in New Jersey has led J. P. Owens, J. P. Minard, and P. D. Blackmon (Art. 263) into studies of the clay-sized sediments in the coastal plain formations of New Jersey. The sediments contain various clays in combination with finely comminuted minerals. The Hornerstown sand contains the distinctive glauconite clay; the Vincentown formation, calcite clay; the Kirkwood formation and Cohansey sand, quartz clay; and the Wenonah formation, chlorite clay. Montmorillonite is predominant in formations younger than the Manasquan. The clay deposits indicate shallow marine to lagoonal and outer neritic depositional environments.

Recent detailed field study and mapping of the Mount Laurel sand of New Jersey by Minard and Owens (Art. 173), supplemented by paleontologic studies by Ruth Todd, show that the Mount Laurel sand is a well-defined mappable unit throughout the State. A fauna from the basal part of the sand contains fossils of probable Navarro age. Fossils from the middle and upper parts of the formation are definitely of Navarro age, clearly indicating that the Mount Laurel belongs in the Monmouth group. Minard and Owens correlate the Kirkwood formation of Miocene age and Cohansey sand of Miocene(?) age, with the Chesapeake group and with the basal part of the Brandywine formation in the Brandywine area of Maryland. The Kirkwood is markedly similar to the deeply eluviated upper part of the Chesapeake group. The Cohansey sand can be recognized in both Maryland and Virginia.

Hydrologic studies

As part of a study of the hydrology of the Coastal Plain of southeastern North Carolina, H. E. LeGrand (1960a) has described three major aquifers that occur in the thick sequence of Coastal Plain sediments. These are: (a) sandstone beds in formations of Cretaceous age, which contain fresh artesian water in the west half of the area studied and salt water in the east half, (b) Tertiary limestone beds, which also contain artesian water, and (c) shallow surface sands, which contain water in reach of shallow drive-point wells. At least two of these aquifers are believed to be available in any part of the area.

The fluctuations of sea water in estuaries along the North Carolina coast under varied conditions of tides, winds, and river discharge have been examined by T. H. Woodard and J. D. Thomas (1960). During October and November 1957, the beginning of the 1958 water year, salt water appeared at the following places: Chowan River near Edenhouse, Pasquotank River at Elizabeth City, Perquimans River at Hertford, and Albermarle Sound near Edenton. The Trent River near Rhems showed salt-water encroachment during October, November, August, and September. Salt water was present in the Neuse River at New Bern during all months except April and May. During periods of normal flow a salt-water body remains at New Bern until a high flow flushes out the salt water.

The piezometric levels of the Cretaceous sand aquifer of the Savannah River basin indicate to G. E. Siple (1960a) that recharge to the aquifer occurs in the topographically high areas east of Aiken, S.C., and southwest of Augusta, Ga. A pronounced depression on the piezometric surface near the Savannah River downstream from Augusta indicates ground-water discharge extending from Augusta downstream to the vicinity of the Aiken-Barnwell County line.

According to J. W. Stewart and M. G. Croft (1960), artesian pressures in the coastal counties of Georgia have declined about 10 to 90 feet since 1943, owing to increased use of ground water for industrial, municipal, and domestic supplies. In 1957 an estimated 279 mgd (million gallons per day) of ground water was discharged in the coastal counties; this amount is about twice that of 1943. The largest withdrawal of ground water was in the Brunswick area, where an estimated 90 mgd was discharged in 1957. Large and well-defined cones of depression occur in the piezometric surface in the Savannah, Brunswick, Jesup, and St. Marys-Fernandina areas. The largest and deepest cone is in the Savannah area, where the piezometric surface is as much as 120 feet below sea level. In the Brunswick area the piezometric surface outside the area of heaviest pumping, is 10 feet above sea level, but the deepest part of the cone probably is as much as 30 to 50 feet below sea level. In this area, the reduction of head by pumping has resulted in an encroachment of connate salt water from deeper limestone aquifers. J. W. Stewart (1960) found that water from the deepest wells contains the largest amount of chloride, and that water from several shallow wells has shown a significant increase in chloride content in recent years.

G. W. Leve (1961) has observed that the piezometric surface in the Fernandina area of northeastern Florida has declined 10 to 60 feet during the period 1880–1960. The ground-water pumpage in the area does not at present exceed the perennial yield of the aquifer, and only slight increases in the salt content of the water have been noted. In Volusia County most, if not all, of the fresh water in the Floridan aquifer is derived from rain falling in the recharge areas within the county, according to G. G. Wyrick (1960a). Stratification in the Floridan aquifer retards or prevents the upward movement of salt water. In contrast, in Martin County, W. F. Lichtler (1960) has found that there are zones of relatively fresh and salt water in the Floridan aquifer. Salt-water encroachment into the shallow nonartesian aquifer has not been extensive, but it is a threat in areas near bodies of salt water.

Hydrologic studies near Fort Lauderdale, Fla., are summarized on page A-93.

EASTERN PLATEAUS

Recent geologic and hydrologic work of general interest in the Eastern Plateaus is described below. Much of this work is carried on in cooperation with State agencies. Work on clay in Kentucky is described on page A-5, and work in the Kentucky-Illinois mining district on page A-3.

Geologic mapping in Kentucky

In south-central Kentucky, R. E. Thaden and others (Art. 39) have delineated limestone reefs in the Fort Payne formation of Early Mississippian age. The reefs, which trend generally N. 65° to 80° W., range in size from small isloated lenses to thick bodies as much as a mile wide and 15 miles long. The reefs are of potential interest for petroleum as the Fort Payne has produced small amounts of oil and natural gas in some areas.

During mapping and study of coal-bearing strata in the Kermit and Varney quadrangles, eastern Kentucky, J. W. Huddle and K. J. Englund have found that sandstone members in the upper part of the Breathitt formation of Early Pennsylvanian age are complex channel-in-channel deposits formed by meandering streams. As these streams shifted course across the coal-forming swamps they reworked previously deposited sand and plant debris. An understanding of the sedimentological history of these sandstones will aid in predicting the persistence and thickness of the underlying coal beds.

Geologic mapping by K. J. Englund (Art. 177) in the southwestern part of the Cumberland overthrust block in the Middlesboro area of southeastern Kentucky, demonstrates that the Cumberland overthrust has been divided into subsidiary blocks by the Rocky Face fault and associated faults. Strike-slip movement along the Rocky Face fault is 1 to 2 miles. At its southeast end, the Rocky Face fault intersects a thrust fault with a similar amount of displacement toward the southeast. The rectangular subsidiary block delineated by this thrust fault on the southeast, the Pine Mountain thrust fault on the northwest, the Rocky Face strike-slip fault on the northeast, and the Jacksboro strike-slip fault on the southwest has rotated relative to the remainder of the Cumberland overthrust block.

Quaternary geology of the lower Ohio River Valley

Continued studies by L. L. Ray indicate that ice sheets of two ages crossed the Ohio River Valley into Kentucky between Louisville and Mentor. The most widespread till, deposited during the first of these two glacial invasions of Kentucky, has been assigned to the Kansan stage primarily because of its deep alteration by weathering. The second ice sheet has been assigned to the Illinoian stage. Small patches of this younger till indicate that the ice crossed the Ohio Valley at several places and pushed small tongues into the lower parts of valleys tributary to the Ohio.

Geologic history of Teays Valley, West Virginia

E. C. Rhodehamel and C. W. Carlston have concluded that Teays Valley in West Virginia was probably abandoned as a major stream channel in late Tertiary or early Pleistocene time, and then was subjected to prolonged weathering. Owing to ponding, probably in Kansan time, laminated silty clay was deposited in the east-central part of the valley, and sand in the remainder. These deposits are now deeply eroded. Probably during Illinoian time, ponding at a lower level resulted in deposition of silty clays in the western part of the valley. During a brief ponding in Wisconsin time, a veneer of ice-rafted pebbles was deposited.

Paleontologic studies

According to J. M. Schopf (Art. 95), coal balls found at three localities in eastern Kentucky are the oldest known in America and the first observed in the Appalachian coal fields. The coal balls occur in the marine Magoffin beds of Morse [5] of early Middle Pennsylvanian (late Kanawha) age. They consist of limestone with more than 90 percent calcium carbonate and about 10 percent plant substance, including many new fossil plants. Coal balls supply important data on the mode of accumulation of coal, and on structure and history of ancient plants.

[5] Morse, W. C., 1931, Pennsylvanian invertebrate fauna: Kentucky Geol. Survey, ser. 6, v. 36, p. 293–348.

Hydrologic studies in Kentucky

A study of the geochemistry of natural waters of Kentucky, by G. E. Hendrickson and R. A. Krieger (1960), has revealed a recurring pattern in the relation of chemical quality of water to stream discharge. Modifications in this pattern reflect differences in the hydrology and geochemistry of the basins.

In a study of the occurrence of ground water in the Blue Grass region of Kentucky, W. N. Palmquist, Jr., and F. R. Hall (1961), observed that only 6 percent of the domestic wells in valley bottoms were failures, whereas 35 percent of the hilltop wells failed to yield an adequate supply.

In the Mammouth Cave area, Kentucky, G. E. Hendrickson (Art. 308) has found that under certain conditions about 60 percent of the water discharged at Echo River outlet is derived from local ground water and 40 percent from the Green River.

The effects of oil field brines and acid mine waters on the composition of Kentucky streams is described on page A–76.

Flood frequency areas in New York

According to F. L. Robison, the Eastern Plateau region of New York can be divided into three flood-frequency areas. The ratios of 10, 25, and 50 year floods to the mean annual floods in the Tug Hill area east of Lake Ontario are very high, whereas the mean annual floods are near the median value for the State. In the Delaware River basin, both the ratios of the longer term floods and the mean annual floods are near the median values. In the rest of the region the longer term ratios are small and the mean annual floods range from high values to some of the lowest.

The results of other hydrologic investigations in the Eastern Plateaus region are given on pages A–92 and A–93.

SHIELD AREA AND UPPER MISSISSIPPI VALLEY

Results of recent geologic, geophysical, and hydrologic studies in the Shield area and in the Upper Mississippi Valley are described in the following paragraphs. Much of this work is carried on in cooperation with State agencies. Additional information on lead-zinc deposits is given on page A–3.

Geologic studies and mapping

The ores in the Wisconsin zinc-lead district were deposited by concentrated brines rich in sodium, calcium, and chlorine, and lean in carbon dioxide, according to preliminary data by W. E. Hall, I. I. Friedman, A. V. Heyl, Jr., and M. R. Brock. Temperature of the solutions was about 100°C. (See p. A–96.)

Minor elements and heavy mineral phenocrysts in volcanic ash of eastern Nebraska and western Iowa are reported by R. D. Miller, E. J. Young, and P. R. Barnett as supporting correlation of the deposits with ash of late Kansan-early Yarmouth age elsewhere in Nebraska and in Kansas.

Lower and middle Precambrian rocks that underlie the Kelso Junction quadrangle, Iron County, Mich., have been found by K. L. Wier to differ from related rocks to the southeast in the following ways: (a) Metagabbro of the West Kiernan sill is more extensive, (b) the metavolcanic Hemlock formation is thicker and contains proportionally more pyroclastic material, and (c) the iron-bearing Amasa formation is practically nonmagnetic.

Rocks in part of southern Florence County, Wis., are believed by C. E. Dutton to be a previously unrecognized upper part of the Michigamme slate of middle Precambrian age because of their apparent relation to rocks in Dickinson County, Mich. An assemblage of phyllite, chlorite and biotite schists, amphibolite, gruneritic iron-formation, conglomeratic quartzite, quartz slate, and volcanic agglomerate is approximately 2,500 feet thick. Some lithologic units crop out along a strike length of almost 8 miles.

In a study of the Marquette iron-bearing district, Michigan, J. E. Gair, R. E. Thaden, and B. J. Jones (Art. 178) have discovered that a synclinal fold at the east end of the district contains strata older than the ore-bearing Negaunee iron-formation. As the fold plunges eastward, the iron formation may exist beneath Lake Superior and the Paleozoic rocks of adjoining areas. At the east end of the Marquette district the Kona dolomite of middle Precambrian age is silicified near some sedimentary and fault contacts in a way that suggests that silica was introduced laterally or upward, rather than downward from an erosional surface (Art. 179).

Streams in sandstone differ from those of the same discharge in till by greater wavelength of meanders (more than 5:1), wider channels, steeper longitudinal profiles, lesser depths, and coarser bed material. These contrasts were recognized by J. T. Hack during a study near Ontonagon, Mich., where stream valleys in some places have been cut through interbedded till and lake deposits into preglacial topographic highs composed of standstone of Keweenawan age.

Geophysical surveys

In parts of Ohio (Geauga, Wayne, Muskingum, Ross, and Montgomery Counties), where glacial till conceals the underlying bed rock, R. M. Hazlewood has determined the depth to bed rock and the location of buried valleys quickly and easily by seismic refraction work. In one area the depth computed seismically was within 1½ percent of that measured in a test drill hole.

According to an interpretation of aeromagnetic data by J. W. Allingham and R. G. Bates (Art. 394), a syenite complex northwest of Wausau, Wis., is intruded by a circular plug that may be of alkalic composition. Spectrographic analyses have shown concentrations of niobium and rare earths in rocks of the syenite complex.

In an area near Florence, Wis., C. E. Dutton and R. W. Johnson, Jr., have reconciled the results of aeromagnetic and geologic surveys. The study shows that anomalies with elongate contour patterns are mainly parallel to thin magnetite-bearing beds or lenses in metamorphosed sedimentary or volcanic rocks. Some anomalies of circular to elliptical pattern are related to concentrations of magnetite of undetermined origin in conglomerate, argillite, or thinly bedded phyllite; others are in localities where geologic data are unavailable.

Geophysical surveys in Minnesota are described on page A–68.

Hydrologic studies

W. D. Mitchell (Art. 6) has developed a method of calculating peak flows of streams affected by artificial storage and having only partial record stations. The method applies to sites where storage is proportional to the outflow discharge but possibly can be expanded to include sites where storage is not proportional.

A method of estimating flood magnitudes and frequencies in Ohio, based on soil and topographic characteristics of drainage areas, has been devised by W. P. Cross and E. E. Webber.

F. A. Watkins and J. S. Rosenshein (1960) have found that about 30,000 gallons of water per day moves under natural gradients through each mile-wide strip of the dolomitic limestone of Silurian age underlying the Bunker Hill Air Force Base near Peru, Ind. Recharge is through the overlying glacial drift.

According to W. L. Steinhilber, O. J. Van Eck, and A. J. Feulner, the St. Peter sandstone in Clayton County, Iowa, is not recharged by the Mississippi River as was previously thought but, on the contrary, the sandstone discharges water to the river. Recharge to the St. Peter is by percolation from the overlying Galena dolomite.

Floods of May 1959, in the Au Gres and Rifle River basins, Michigan, according to L. E. Stoimenoff (1960), resulted in the highest unit discharges for areas less than 15 square miles ever measured in the lower peninsula of Michigan.

Robert Schneider and H. G. Rodis have found that the sand and gravel aquifers of Lyon County, Minn., are glacial outwash deposits that parallel the moraines but are thickened along southeast-trending channels. Some of the outwash was overridden by readvances of the ice and where the drift is thick the aquifers may have no topographic expression.

According to W. C. Walton and G. D. Scudder (1960), pumpage of ground water in the Fairborn area of Green County, Ohio, can be increased from the present 6.5 million gallons a day to 50 million gallons a day without seriously affecting ground-water levels. Such an increase would induce infiltration of water into extensive outwash deposits along the Mad River. The river has a base flow of about 150 million gallons a day.

Tracing of till sheets in northeastern Ohio by G. W. White (1960 and Art. 176), has led to the recognition by S. E. Norris and G. W. White (Art. 17) of many buried valleys. These valleys, cut into older glacial drift and filled with younger drift, have an important bearing on the occurrence of ground water. A map of the glacial deposits of Ohio, recently completed by R. P. Goldthwait and others, will greatly aid in the application of glacial geology to water resources investigations.

Sediment yields during the floods of early 1959 in Ohio were low for the rate of streamflow because the ground was frozen and consequently was more resistant to erosion. R. J. Archer (1960) reported that in the floods of January 1959, sediment yields exceeded 200 tons per square mile in the Scioto River basin. In the floods of February 1959, the sediment yield in the Maumee River basin above Waterville was 121 tons per square mile.

Studies of Paleozoic aquifers in Fond du Lac County, Wis., by T. G. Newport indicate that a decline of as much as 200 feet in water levels at Fond du Lac can be relieved by placing new wells to the northwest, toward the recharge area, and by utilizing water from the Niagara dolomite to the east.

Other hydrologic studies in the region are reported on Pages A–92 and A–93.

GULF COASTAL PLAIN AND MISSISSIPPI EMBAYMENT

Geologic and hydrologic investigations in the Gulf Coastal Plain and Mississippi Embayment are both regional and local in scope. They have supplied data that have contributed much to economic development as well as to knowledge of the regional geology. Some of the more significant results of these studies are described below. The origin of uranium deposits in Karnes and adjoining counties, Texas, is discussed on page A–7.

Correlation of the Carrizo sand in central Mississippi Embayment

By the use of electrical logs, R. L. Hosman has traced the Carrizo sand, the basal unit of the Claiborne group in Arkansas, from Louisiana northward into Arkansas along the strike and thence eastward across the axis of the Mississippi structural trough into Mississippi.

Pliocene(?) stratigraphy of the northern Mississippi Embayment

During the course of geologic investigations in the southern part of the Jackson Purchase area of western Kentucky, being conducted in cooperation with the Kentucky Geological Survey, W. W. Olive, R. W. Davis, and T. W. Lambert have found that fluvial sediments previously mapped as the Lafayette formation of Pliocene age and as sand and gravel of Pliocene and Pleistocene ages comprise a sequence consisting of a lower and an upper unit composed dominantly of gravel and sand, and a middle unit consisting mainly of clay beds. The maximum thickness of the sequence is about 80 feet. The lower and upper gravel units are as much as 40 and 20 feet thick, respectively, and the clay unit is from 5 to 40 feet thick. These deposits lie on an erosion surface of gentle to moderate relief cut in older Tertiary sediments. The basal unit thins, grades into sand, or is absent above the crests of buried hills.

Effects of Pleistocene and Recent weathering of Tertiary sediments

According to I. G. Sohn, S. M. Herrick, and T. W. Lambert (Art. 94), calcareous foraminiferal shells from Paleocene strata near Paducah, Ky., have been replaced by a zeolite and possibly barite. Microfaunas are rare in these rocks and this fact plus the fact that the $CaCO_3$ has been replaced by relatively insoluble minerals provide indirect evidence to support a previous suggestion that prolonged leaching has removed calcareous material from Cretaceous and Tertiary rocks of the northern Mississippi Embayment.

In the uranium-producing area of southeast Texas, A. D. Weeks has also observed that weathering of Tertiary sediments has resulted in the formation of zeolites. Other weathering effects in this area include the formation of a caliche crust of calcium carbonate in the soil and the release of silica from tuffs. The released silica has cemented sands to form orthoquartzites.

Ground-water storage

In the San Antonio, Tex., area a long drought was broken by rains in 1957–58, and as a result the water levels in many parts of the aquifer in the Edwards limestone recovered from a record low in 1957 to a near record high in the spring of 1961. On the basis of this measured rise in water level, Sergio Garza estimates nearly 2 million acre-feet of water was added to storage in the ground-water reservoir between 1957 and 1961.

A. H. Harder reports that 212 billion gallons of ground water was pumped for all purposes from the main aquifer in the rice-farming area of southwestern Louisiana during 1959. In spite of this large annual withdrawal, the weighted-average water level computed for the entire area has not been lowered but has remained virtually the same since 1955.

New sources of ground water

Separate investigations in northeastern Mississippi and west-central Alabama indicate that large ground-water supplies may be available from the Tuscaloosa group of Cretaceous age. A newly drilled well near Columbus, Miss., flowed 2,300 gpm from the aquifer of Cretaceous age. Electrical logs and water samples from oil-test wells show that fresh water occurs to a depth of about 2,000 feet in the Tuscaloosa group of west-central Alabama.

As a result of the hydrologic studies made on behalf of the Atomic Energy Commission to improve techniques for detecting underground nuclear explosions, at least four fresh-water aquifers in Miocene and Oligocene strata have been discovered near the Bruinsburg and Tatum salt domes in Mississippi. Another aquifer contains salt water and may be used for brine disposal if mining in the salt domes by solution methods is undertaken.

Roy Newcome, Jr. (1960), has shown by hydrologic tests that the alluvial aquifer along the Red River in Louisiana is capable of supplying much larger quantities of water than believed previously.

G. T. Cardwell and J. R. Rollo (1960) report that the shallow-point bar deposits of Recent age along the Mississippi River south of Baton Rouge, La., are a potential source of fresh water but are virtually untapped. Although the deposits are fine grained they are in hydraulic connection with the river and would yield a dependable supply of water.

Occurrence of salt water

J. R. Rollo (1960) has used electrical logs and completion data on oil and water wells to construct a fence diagram and a contour map showing the altitude of the base of fresh water and its relation to the subsurface geology in Louisiana. The contact between salt and fresh water reflects regional as well as many minor geologic structures.

Although invasion of salt water was not extensive along the Gulf Coast during 1961, water from wells in the Houston and Galveston areas, Texas, showed slightly increased mineralization. G. T. Cardwell reported an increase in chloride content of water in a Pleistocene aquifer in Ascension Parish, La., caused by increased withdrawals.

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OZARK REGION AND EASTERN PLAINS

Recent work in the Ozark Region and Eastern Plains, carried on in part in cooperation with State agencies, has yielded a considerable amount of geologic and hydrologic information of regional significance, which is summarized below. Additional information on evaporite deposits in New Mexico is given on pages A-6 and A-7, and information on coal in Arkansas is given on page A-8.

Aeromagnetic studies in northeastern Arkansas and southeastern Missouri

Aeromagnetic data indicate that the crystalline basement is about 1 mile below the surface at the point where the White River crosses the Ozark escarpment near Newport, Ark. In Stoddard County, Mo., magnetic data indicate that the basement is about 3,000 feet below the surface.

Arkoma basin, Arkansas and Oklahoma

Subsurface studies by E. E. Glick, B. R. Haley, E. A. Merewether, and S. E. Frezon indicate that within the Arkoma basin in Arkansas and Oklahoma the Atoka formation of Pennsylvanian age contains as many as 4 thin beds or zones of bentonite. The areal and stratigraphic distribution, and the mineralogy of these beds indicate that they will be useful in studies of the depositional history of the Atoka formation and of the developmental history of the basin (Frezon and Schultz, Art. 181).

Atoka formation in the Arkansas Valley, Arkansas

The Atoka formation of Pennsylvanian age in the central part of the Arkansas Valley, Ark., increases in thickness from about 3,050 feet in northern Johnson County to about 10,750 feet in northern Yell County, a distance of 28 miles. E. A. Merewether (Art. 182) has reported that the southward thickening results largely from an increase in the shale units in the formation.

Development of the Fredonia anticline in Wilson County, Kansas

Analysis of measured sections and well records in Wilson County, Kans., by H. C. Wagner has shown that uplift on the Fredonia anticline began in Mississippian time and continued intermittently through Pennsylvanian time. The uplift controlled, to some degree, places of accumulation of sand and limestone debris, which later served as petroleum reservoirs. Movement on the Fredonia anticline during Late Pennsylvanian time is well documented in measured surface sections.

Austin chalk, Val Verde and Terrell Counties, Texas

The concept of a widespread hiatus at the base of the Austin chalk is not supported by findings of V. L. Freeman (1961), who reports that neither a depositional or erosional break nor a faunal gap is present at the base of the unit in Val Verde and Terrell Counties, Tex. In addition, the lowest beds assigned to the Austin chalk, previously considered to be of Coniacian age, are now considered by Freeman to be of Turonian age.

Movement underground of artificially-induced brine

As part of a study of the geology and water resources of Cowley County, Kans., C. K. Bayne has obtained data on the movement of underground water. More than 30 years ago a moderate amount of highly mineralized oil field brine was discharged by means of a well into an aquifer in terrace deposits in the Arkansas River valley near Winfield. This brine is now moving down the valley as a discrete body at a rate of about a quarter of a mile per year.

Buried valley near Manhattan, Kansas

According to H. V. Beck (Art. 351) a buried valley northwest of Manhattan, Kans., was occupied by the Kansas River in pre-Kansan time and possibly as late as Illinoian time. Later, the Kansas River changed its course when a meander cut through the area between Bluemont Hill and K Hill. The gravel in the buried valley is an important source of ground water.

Depressions on the High Plains

As part of a study of artificial recharge, test holes were drilled across closed depressions on the High Plains. They show that the caliche caprock generally present beneath the surface of the plain dips toward the centers of the depressions, thins from the outer margins toward the centers, and is absent at the centers. J. S. Havens (Art. 52) has therefore concluded that the depressions have been caused by solution of the caliche caprock and have been further deepened by removal of sand by deflation.

Salt water and halite at shallow depths in Oklahoma

Recent work by P. E. Ward and A. R. Leonard (Art. 341) has shown that salt and salt water underlie large areas in western Oklahoma at shallow depths. The salt, which occurs as beds, lenses, and stringers of halite interbedded with Permian shale, siltstone, dolomite, and gypsum, is within 200 feet of the land surface in a few places in northwestern and southwestern Oklahoma, and at one place in Woods County it was found at a depth of 70 feet in a core hole.

Although shallow mineralized salt water is associated with halite in many places, it occurs in the absence of halite in many others. Around some geologic structures, the depth to salt water changes markedly within short distances. Maps being compiled by D. L. Hart, Jr., show that the depth to salt water in one place in south-central Oklahoma increases from 400 feet to 1,100 feet in a distance of 4 miles. In many places, salty water is within 200 feet of the land surface, particularly in western Oklahoma.

In contrast to the shallow salt water, potable ground water extends to depths of a few hundred feet in several of the red-bed sandstones of Pennsylvanian and Permian age. In the Arbuckle limestone in south-central Oklahoma, fresh ground water extends to depths of more than 2,500 feet.

Water withdrawal in Reeves County, Texas

According to William Ogilbee and J. F. Wesselman, water for irrigation in Reeves County, Tex., is being withdrawn from the aquifer at a much greater rate than the rate of recharge. The number of irrigation wells in the county has increased from 60 in 1946 to more than 900 in 1959. The water levels in the heavily pumped area have declined persistently since 1946, the maximum decline being about 200 feet. In 1958, about 40 million acre-feet of water remained in storage, but only a part of this water is available to wells.

Aquifer filled in Haskel and Knox Counties, Texas

William Ogilbee and F. L. Osborne, Jr., have reported that the Seymore formation in Haskel and Knox Counties, which 60 years ago contained only small quantities of saline water near the base, is now completely filled. The Seymore formation is a thin alluvial deposit overlying red beds of Permian age. The rise in the water level is attributed to the beginning of cultivation and the consequent removal of the large growth of mesquite and other phreatophytic vegetation.

Reservoir evaporation

As part of a study of evaporation and seepage losses from reservoirs in the Honey Creek basin, 35 miles north of Dallas, Tex., F. W. Kennon (Art. 50) has concluded that the average annual evaporation for a typical small reservoir is 5.1 feet. The average annual precipitation for the period 1953–59 was 2.9 feet. Hence, the net annual evaporation loss was 2.2 feet.

NORTHERN ROCKIES AND PLAINS

Geologic, geophysical, and ground-water studies are being carried on in the Northern Rocky Mountains and Plains in many areas of widely different characteristics. Some of the recent findings resulting from these studies are summarized below. Additional information on mineral deposits is given on pages A–1 to A–8. The origin of carbonatites in the Bearpaw Mountains, Mont., is discussed on page A–77, and the isotopic composition of lead in major ore deposits in the region is discussed on page A–96.

Geologic studies in northeastern Washington and northern Idaho

According to R. G. Yates the lead-zinc deposits in the Northport mining district, northern Stevens County, Wash., are thermally related to, but not necessarily derived from, the Spirit pluton, a granodiorite mass of probable Cretaceous age.

In the Hunters quadrangle, mapping by A. B. Campbell indicates that the Old Dominion limestone of Weaver[6], equivalent at least in part to the Cambrian Metaline limestone, overlaps the Maitlen phyllite from north to south. New paleontologic evidence suggests that the Old Dominion is younger in the vicinity of Hunters, Wash., than rocks of the same lithologic facies farther north.

In the Mount Spokane and Greenacres quadrangles and in adjacent areas, A. E. Weissenborn, P. L. Weis, and V. C. Fryklund have recognized Belt rocks of Precambrian age. This occurrence is farther west than any recognized previously. In the Mount Spokane quadrangle, Weissenborn has shown that meta-autunite is restricted to a muscovite-quartz monzonite in which mafic minerals are sparse or absent.

In the Clark Fork area of Odaho, J. E. Harrison and others (Art. 67) attribute mosaic block faulting in Belt rocks to vertical adjustment of the crustal rocks during emplacement of a granodiorite batholith in Cretaceous time. The existence of the still-buried batholith is indicated by positive magnetic anomalies, by scattered outcrops of small stocks, and by small areas of higher grade metamorphism in the Belt rocks.

Geologic studies in central Idaho

In the vicinity of the northwest margin of the Idaho batholith, Anna Hietanen (Art. 345) has found that the grade of metamorphism in the country rocks increases progressivly towards the batholith from the greenschist facies to the amphibolite facies. In general, the type of folding also changes with increasing metamorphic grade—open folds are typical of the greenschist facies, and isoclinal flow folds are typical of the amphibolite facies near the batholith.

In a study of the Idaho batholith in the Yellow Pine quadrangle, B. F. Leonard has recognized a small outlier of Challis volcanics of Tertiary age near Riordan Lake, about 10 miles farther southwest than this unit of flow and pyroclastic rocks had been traced previously. Heat and solution from the volcanic mass have

[6] Weaver, C. E., 1920, The mineral resources of Stevens County: Washington Geol. Survey Bull. no. 20.

caused mild argillization of the underlying granodiorite of the Idaho batholith, and have induced retrograde metamorphism in sillimanite-biotite schist and marble inclusions in the granodiorite.

Four glacial stages, one probably of early Pleistocene age, have been recognized by E. T. Ruppel and M. H. Hait, Jr., (Art. 68), in the central part of the Lemhi Range, and the relation of deposits laid down during these stages to landforms suggests the presence of remnants of a preglacial pedimentlike surface. The central part of the Lemhi Range is underlain mainly by Precambrian and early Paleozoic rocks that are folded into a large overturned anticline and broken by a number of west-dipping overthrust faults.

Geologic and geophysical studies in western Montana

In the western part of the Sun River Canyon area, M. R. Mudge reports the presence of a western facies of the Ferdig shale member of the Upper Cretaceous Marias River shale. The western facies is dominantly fine- to medium-grained sandstone with minor amounts of interbedded mudstone, whereas the eastern facies is mainly silty mudstone with minor amounts of interbedded fine-grained sandstone. A slightly different fauna occurs in each facies. The western facies is similar in lithology and fauna to the Cardium standstone of Alberta.

In the Wolf Creek area, R. G. Schmidt (Art. 211) has recognized a low-angle fault called the Cobern Mountain overthrust. Along this fault, rocks of the Two Medicine formation of Late Cretaceous age and overlying rocks of the Adel Mountain volcanics of Lyons[7] have been thrust northeastward upon younger rocks of the Adel Mountain volcanics. In the vicinity of Cobern Mountain the net slip along this fault is more than 2 miles and the fault plane is folded. The structural relations along the Cobern Mountain overthrust, together with the occurrence of fossils of supposed Horsethief age beneath rocks of the Adel Mountain volcanics (notably at Cobern Mountain), indicate that the Adel Mountain volcanics are probably equivalent to part of the Saint Mary River formation of Late Cretaceous age and are thus considerably younger than the volcanic rocks of the Two Medicine formation.

Geophysical studies by W. T. Kinoshita and W. E. Davis in the Townsend Valley and Three Forks basin indicate that most of the major structural features known from surface mapping are outlined by magnetic anomalies associated with igneous and metamorphic rocks. A strong anomaly in the eastern part of the Townsend Valley shows that the Lombard overthrust extends northward beneath the Cenozoic fill in the valley to join with thrust faults along the west flank of the Big Belt Mountains southeast of Canyon Ferry. Another anomaly in the western part of the Three Forks basin indicates that the Jefferson Canyon thrust fault swings northeastward to join a thrust zone a few miles southwest of Three Forks junction. The magnetic anomalies also indicate that the anticlines exposed in the Limestone Hills and the Hossfeldt Hills are parts of a continuous structure, the southern part of which has been offset eastward about 2 miles, probably along a series of northwest-trending faults.

Near Livingston, the Madison group has been shown by A. E. Roberts (Art. 126) to be a carbonate sequence of many marine cycles alternating between calcium and magnesium deposition during Kinderhook, Osage, and Meramec time. Insoluble residue samples from the upper member of the group contain a phosphate-sulphate mineral suggesting a lithofacies relation with evaporite-dolomite rocks of the Charles formation farther northeast.

In the Greenhorn and Gravelly Ranges, west of the Madison River, the Precambrian and Paleozoic rocks have been displaced several miles, according to J. B. Hadley. In the northern part of the Gravelly Range, Hadley has found remnants of thin rhyolite ash flows, in part welded, that may be marginal deposits of the Tertiary Yellowstone volcanic province.

In the Highland Mountains south of Butte, M. R. Klepper and H. W. Smedes have mapped three well-defined east-trending plutons in the southern part of the Boulder batholith. The batholith margin in this area apparently was controlled in large part by an east-trending prebatholith fault zone, along which the plutons were emplaced.

At the eastern border of the Idaho batholith, in the headwaters of the West Fork of the Bitterroot River, geologic mapping by R. L. Parker has shown that phyllite, quartzite, and schist (believed to be part of the Precambrian Belt series) grade into gneiss along a contact that parallels the schistosity in both the gneiss and the schist. Apparently both the gneiss and the schist were formed from Belt rocks by metamorphism that accompanied emplacement of the Idaho batholith, and the gneissic rocks, therefore, are not pre-Belt metamorphic rocks as had been supposed previously.

Alternative hypotheses on deformation accompanying the Hebgen Lake earthquake, Montana

Studies in the vicinity of Hebgen Lake since the disastrous earthquake of August 17, 1959, have led to two somewhat different hypotheses to account for the observed deformation. The dual-basin hypothesis, set forth by I. J. Witkind (Art. 346), suggests that two separate basins were simultaneously deformed by re-

[7] Lyons, J. B., 1944, Igneous rocks of the Northern Big Belt range, Montana: Geol. Soc. America Bull., v. 55, no. 4, p. 449, 452.

newed movement along existing range front faults bordering northwest-trending tilted fault blocks. The single-basin hypothesis, proposed by W. B. Myers and Warren Hamilton (Art. 347), sugests that the structures of the east-trending Centennial Range and Valley are being extended across the north- and northwest-trending structures of the Madison Range and flanking valleys, to define a new structural basin that ends obliquely and abruptly against reactivated northwest-trending faults northeast of Hebgen Lake.

Geologic and geophysical studies in the Bearpaw Mountains, Montana

Geologic mapping by B. C. Hearn, Jr., and W. C. Swadley in the southeastern part of the Bearpaw Mountains has disclosed a ringlike belt of intrusive igneous rocks and severely deformed volcanic and sedimentary rocks 3 to 5 miles wide surrounding a central area of about 15 square miles that is less deformed and is almost devoid of igneous rocks. In the ringlike belt, collapse faults are common. The aggregate stratigraphic displacement on some of the faults is as much as 9,000 feet.

In the western Bearpaw Mountains, K. G. Books has found a close association between magnetic anomalies and topographic highs, which he believes indicates a relatively thin cover of volcanic rocks. This conclusion is supported by rock thicknesses calculated from remanent magnetic data.

Geologic and geophysical studies in parts of Wyoming, southeastern Idaho, and northeastern Utah

In the northwestern part of Park County, Wyo., W. G. Pierce has mapped a decollement type of fault, the Reef Creek detachment fault. The fault is slightly older than the Heart Mountain detachment fault, and the rocks moved on the Reef Creek fault have been scattered still farther by transportation atop masses moved by the Heart Mountain fault.

Gravity measurements by L. C. Pakiser and H. L. Baldwin, Jr., (Art. 104) at 890 stations in Yellowstone National Park and adjoining parts of Idaho, Montana, and Wyoming reveal a strong gravity low in the vicinity of the Yellowstone Plateau, and a narrow gravity low along the Madison Valley, Mont. (See p. A–70.)

In the Afton area, western Wyoming, J. D. Love (Art. 250) reports large reserves of vanadium in phosphate rock of the Phosphoria formation. (See p. A–4.)

In the Fossil Basin, north and west of Kemmerer, Wyo., W. W. Rubey, S. S. Oriel, and J. I. Tracey (Art. 64) have studied the Upper Cretaceous and Lower Tertiary rocks in detail. They conclude, on the basis of fossil vertebrates, mollusks, leaves, and pollen, that the Evanston formation is of latest Cretaceous to early late Paleocene age. They also recognize a peripheral diamictite facies (Art. 62) in the Wasatch formation in the Fossil Basin, and suggest its accumulation through mudflow and solifluction.

Northwest of Nounan, Idaho, mapping by F. C. Armstrong shows that what has been thought to be part of a thrust plate of Ordovician quartzite resting on Triassic limestone is actually a landslide mass of Cambrian quartzite.

In the upper Green River Valley, Utah, W. R. Hansen finds that the Uinta anticline is a large composite fold having two main closures alined on a single east-trending axis. One closure is centered near Gilbert Peak, and the other near Browns Park. Hansen's work has also shown that large scale normal faulting began in the northeastern Uinta Mountains in early Tertiary time, possibly in the Oligocene, before the cutting of the Gilbert Peak erosion surface. The cutting of the erosion surface later was terminated by renewed faulting and warping.

Studies by W. H. Bradley of the paleohydrology and paleoclimatology of the Eocene Green River formation of Wyoming have revealed that in a period of about 1 million years during the middle Eocene, the climate of Wyoming changed from moist to arid (as arid as the Great Salt Lake area today) and then became moist again. (See p. A–78.)

Stratigraphic studies in parts of eastern Montana and Wyoming

Studies of the Pierre shale by J. R. Gill (Art. 352) show that the formation comprises a series of transgressive deposits that wedge out eastward. The Sharon Springs member of the Pierre consists of widespread persistent beds of bentonite and organic-rich shale which provide an easily identifiable marker for subsurface and surface investigations. Paleontologic studies by W. A. Cobban have shown that this unit contains a distinctive ammonite fauna, indicating that it is an excellent time marker as well as a distinctive lithologic marker. (See also p. A–79.)

Geologic and geophysical studies in the Black Hills, South Dakota and Wyoming

Study of about 110 samples of rocks of the Inyan Kara group by L. G. Schultz and W. J. Mapel (Art. 210) shows that the Lakota and overlying Fall River formations contain the same clay minerals but in different proportions. A zone of kaolinite and ferruginous spherules at the top of the Lakota formation indicates a weathered zone at the Lakota-Fall River contact. The relations are similar to those described at the same horizon along the Colorado Front Range, suggesting that the period of weathering may have been of regional extent. The kaolinite zone may aid in correlating Lower Cretaceous rocks in the Western Interior.

In the southern Black Hills, recent work by G. B. Gott, E. V. Post, and D. E. Wolcott on rocks of the Inyan Kara group has shown that all the major conglomeratic sandstones are in the Fuson member of the Lakota formation, and that the Fuson member constitutes nearly all the Lakota formation in the northwestern Black Hills. The Chilson member of the Lakota formation as defined by E. V. Post and Henry Bell III (Art. 349) is largely restricted to the southern Black Hills.

Preliminary interpretation by R. M. Hazlewood of data from a gravity survey of the Black Hills shows that there is a steep gravity gradient along the west flank of the northern Black Hills, and that there is excellent correlation between gravity data and known geology. The east flank of the Black Hills is characterized by a series of gravity highs and lows that trend parallel to the uplift. In the central part of the Black Hills most of the small anomalies are associated with amphibolite bodies.

Possible Early Devonian seaway

An Early Devonian seaway, which may have occupied a geosynclinal trough west of the present Rocky Mountains, has been inferred by C. A. Sandberg (1961b) as an outgrowth of his study of Devonian stratigraphy in the Williston basin. The Beartooth Butte formation and equivalent strata in the northern Rocky Mountain region were deposited along the eastern margin of the sea. Discontinuous sparsely fossiliferous shallow-water deposits of similar lithology and stratigraphic position are reported from the Northwest Territories in Canada to east-central and southern Arizona. The distribution of these rocks suggests that the Early Devonian seaway may have extended from the Arctic Ocean as far south as the Mexican border.

Biostratigraphic studies of upper Paleozoic rocks

Analysis by W. J. Sando and J. T. Dutro, Jr., of brachiopod and coral faunas in the Madison group and equivalent rocks in the northern Rocky Mountains suggests correlations with the Mississippian of the Mississippi Valley type region. The lower half of the Lodgepole limestone is approximately correlative with the upper part of the Kinderhook (Chouteau equivalents). The upper part of the Lodgepole and lower part of the Mission Canyon (including the related Brazer dolomite) are of Osage age, whereas the uppermost Mission Canyon is considered to be of Meramec age. Fasciculate lithostrotionoid corals, together with certain spiriferoid brachiopods, lend credence to the Meramec correlation. Kinderhook-Osage and Osage-Meramec boundaries are difficult to determine in Madison rocks because of apparent overlapping of ranges of fossils characteristic of the series in the type region.

Endothyrid Foraminifera in Carboniferous rocks of the Mackay quadrangle, Idaho, have been shown by Betty A. L. Skipp (Art. 236) to range in age from Early Mississippian to Pennsylvanian, and to be useful for interpretation of stratigraphic relations in the thick sequence of miogeosynclinal rocks of that area.

Recent collections of Permian corals from the Phosphoria, Park City, and Shedhorn formations have been studied by Helen Duncan (Art. 99), and have added data on the geographic distribution of a coral zone that is fairly widely developed in the Lower Permian rocks of Idaho, Wyoming, and Montana. The presence of corals in these rocks had not been recognized earlier.

Ground-water investigations in Idaho

Many of the larger consumers of water in the Moscow Basin, Latah County, Idaho, depend on artesian aquifers in the Latah formation (Stevens, 1960). Large withdrawals from this formation for more than 60 years have caused a continuing decline in artesian pressure, which has been accelerated during the last few years. Use of surface water is suggested both as a supplemental source and for artificial recharge of the aquifers.

Ground-water investigations in Montana

The northern part of the Deer Lodge Valley contains a thick section of Eocene, Miocene, Pliocene, and Quaternary deposits laid down in a structural valley formed in Late Cretaceous or Paleocene time (Konizeski, McMurtrey, and Brietkrietz, 1961). Moderately large supplies of water are obtained from both the Tertiary and the Quaternary deposits.

In northeastern Blaine County, the Flaxville formation, which underlies a plateau known as the Big Flat, contains an estimated 300,000 acre-feet of water in storage, and receives about 5,000 acre-feet per year of recharge (Zimmerman, 1960). Wells in the Flaxville yield large supplies of water of good quality, whereas only small supplies of generally poor quality water are obtainable from the underlying Upper Cretaceous formations.

Ground-water investigations in Wyoming

An investigation in the vicinity of Osage, Weston County, by H. A. Whitcomb has revealed that the flow of artesian wells tapping the Lakota formation has declined considerably in the last 20 to 30 years, and that some of the wells no longer flow. The declines in flow are attributed mainly to increased withdrawal, but in part to decreased recharge and to possible deterioration of well casings or incrustation of perforations in casings.

In northern and western Crook County, Whitcomb has found that moderate to large supplies of water are obtainable from deep artesian wells tapping the Minnelusa formation and underlying Pahasapa limestone. The Fall River and Lakota formations are the most widely developed aquifers in the area, but generally yield only small supplies of water.

Whitcomb has also found that the Arikaree formation is a moderately good aquifer in the southern part of Niobrara County where well yields range from 150 to 750 gpm (gallons per minute) and average 500 gpm. Wells near the Hartville Hills generally have the higher yields owing to fracturing of the Arikaree by post-Miocene uplift. An estimated 5 to 8 million gallons per day moves eastward through the Arikaree into Nebraska.

Ground-water investigations in North Dakota

Studies in Burleigh, Kidder, and Stutsman Counties, N. Dak., reveal that the larger yields of ground water are obtained from outwash plains, valley outwash, and buried preglacial or interglacial channels that contain stratified sand and gravel, but some water is obtained from lenses of stratified material within till. Near Alexander, McKenzie County, small supplies of water of relatively poor quality are obtained from beds of sand and lignite in the Tongue River member of the Fort Union formation, and from alluvium and colluvium.

Ground-water investigations in South Dakota

A statewide study of artesian wells in South Dakota, by R. W. Davis and others (1961), has revealed that 16 million gallons of water per day is being discharged by 44 uncontrolled flowing artesian wells in the Missouri River Valley. Most of these wells tap the Dakota sandstone. Near the Black Hills, flowing wells yield large quantities of water from the Minnelusa sandstone and Pahasapa limestone. At least nine other artesian aquifers are tapped by wells in western South Dakota. The piezometric surface for wells tapping the Fall River formation has declined about 10 feet since 1956 near Edgemont, in the southern Black Hills, but has not declined since 1959 in eastern Custer County.

SOUTHERN ROCKIES AND PLAINS

Geologic and hydrologic investigations in the Southern Rockies and Plains during the fiscal year 1961 have yielded results of regional or broad local significance in the many fields summarized below. Other results are presented in other sections of this report as follows: mineral deposits, pages A–1 to A–8; geophysical studies, page A–70; engineering studies, page A–88; and geochemical prospecting, page A–95.

Geology of volcanic terrains in Colorado and New Mexico

In the San Juan Mountains, Colo., geologic mapping by R. G. Luedke in the area north of and between the Silverton and Lake City calderas of late Tertiary age has confirmed the suspected occurrence of an older and larger caldera or volcano-tectonic depression upon which were superposed the two younger calderas. Following a catastrophic eruption of welded ash-flow tuffs (Eureka rhyolite of the Miocene Silverton volcanic series), there was cauldron subsidence followed by doming and establishment of a northeast-trending central graben. Continued mapping around the Creede caldera by T. A. Steven and J. C. Ratté disclosed a major graben extending southeast from the caldera in the vicinity of the Rio Grande. The Wagon Wheel Gap fluorspar mine is along one of these graben faults, but no other mineral deposits have yet been discovered.

In the Powderhorn district, Colorado, on the north margin of the San Juan volcanic field, J. C. Olson and D. C. Hedlund have found that the volcanic rocks of Tertiary age include a distinctive sequence of four principal welded-tuff units. Each unit commonly comprises several mappable lithologic varieties, including vitric and devitrified welded tuff and unconsolidated tuff. The similar lithologic succession in different areas indicates the wide lateral extent of each welded-tuff unit.

Mapping of the volcanic rocks of the Jemez Mountains, N. Mex., by R. L. Smith, R. A. Bailey, and C. S. Ross (Art. 340) shows that the Valles caldera contains a complexly faulted central structural dome encircled by a peripheral ring of volcanic domes that are analogous at depth to a central stock and ring dike. Time and spatial relations of doming and vulcanism indicate that some ring dikes were intruded during postsubsidence doming of the caldera floor rather than during cauldron subsidence as suggested by Clough, Maufe, and Bailey[8] in their classic study of the Glen Coe cauldron of Scotland.

Geology of Precambrian rocks

Continued studies in the east-central part of the Front Range, Colo., by J. D. Wells, D. M. Sheridan, and A. L. Albee (Art. 196) indicate that the biotite gneisses of the Idaho Springs formation and the quartz-

[8] Clough, C. T., Maufe, H. B., and Bailey, E. B., 1909, The cauldron-subsidence of Glen Coe, and the associated igneous phenomena: Geol. Soc. London Quart. Jour., v. 65, p. 669.

ite along Coal Creek were deformed twice by plastic deformation and once by cataclastic deformation during Precambrian time. The cataclastic deformation is confined to the recently named Idaho Springs-Ralston shear zone and aside from faulting is the youngest episode of Precambrian tectonism recognized in this part of the Front Range.

Geological mapping of the Precambrian rocks in the drainage of the Gunnison River, in southwestern Colorado, is delineating the lithologic succession and metamorphic and intrusive history of this previously little known complex. In the Powderhorn district, J. C. Olson and D. C. Hedlund have distinguished three principal groups of layered metamorphic rocks: (a) hornblende schist or greenstone, consisting dominantly of metamorphosed basaltic to andesitic volcanic rocks, (b) felsitic volcanic rocks, and (c) quartz-biotite schist, consisting principally of metasedimentary rocks. Some of the metasedimentary layers associated with the felsitic volcanic rocks contain staurolite and kyanite. Nearby, in the Black Canyon of the Gunnison, mapping by W. R. Hansen has disclosed that the dominant Precambrian schist is intruded, from oldest to youngest, by (a) pegmatites, (b) lamprophyric dikes (in upper canyon), (d) quartz monzonite plutons, (d) Curecanti granite (in upper canyon) and Vernal Mesa granite (in lower canyon), (e) pegmatite and aplite, and (f) diabase.

Geology of major sedimentary basins

In the southwestern part of North Park, Colo., mapping by W. J. Hail, Jr., shows that the lower (Paleocene) part of the Coalmont formation overlaps the entire sedimentary sequence of pre-Tertiary rocks and, to the west in the Park Range, lies directly on Precambrian crystalline rocks.

On the western margin of the Denver basin, oil-producing anticlines at Berthoud, Colo., and at Haystack Mountain north of Boulder, Colo., have been delineated in detail by W. A. Cobban and G. R. Scott by means of mapping of ammonite zones in the Pierre shale. To the north, in southeastern Wyoming, L. W. McGrew has recognized the following previously unknown Cenozoic rock units: (a) Early Eocene(?) conglomerate that lies with angular discordance on Permian red beds and is overlain with angular discordance by the White River formation, (b) fluvial and lacustrine deposits of middle to late Miocene age, (c) fluvial deposits of Pliocene(?) age in fault contact with the Arikaree formation (Miocene), and (d) middle to late Pleistocene fluvial and lacustrine deposits that lie 800 feet and 300 feet respectively above the present level of the North Platte River.

According to D. L. Gaskill (Art. 96) the Ohio Creek conglomerate of the Anthracite basin area, about 20 miles north-northwest of Gunnison, Colo., now has been dated as Paleocene on the basis of plant fossils. The conglomerate unconformably overlies strata assigned to the Mesaverde formation over a wide area in the eastern part of the Uinta Basin; it is overlain by the Tertiary Wasatch formation.

Rocks of Mississippian and probable Devonian age in the Sangre de Cristo Mountains

On the basis of stratigraphic studies in the Sangre de Cristo Mountains of northern New Mexico, E. H. Baltz and C. B. Read (1960) report two new formations. The Espiritu Santo formation of Devonian(?) age consists of sandstone, sandy dolomitic limestone, and crystalline and clastic limestone. The Tererro formation, separated from the Espiritu Santo formation by an erosional unconformity, contains three recognizable members—the Macho, Manuelitas, and Cowles. The formation consists of limestone breccia and conglomerate, crystalline limestone, and calcarenite. A sparse faunule in the Manuelitas member indicates an Early Mississippian age for that part of the formation.

Geology of parts of Nebraska

Studies in the southern part of Nebraska by R. D. Miller, Richard Van Horn, Ernest Dobrovolny, and the late L. P. Buck indicate that volcanic ash exposed along the Republican River correlates with the Pearlette ash member of Kansas. The ash is included within the Sappa formation of late Kansan age and provides a widespread, reliable, and easily recognizable stratigraphic marker.

Alluvial terrace deposits along North Loup River in central Nebraska were formed about 10,850 years ago, according to carbon-14 determinations of shell material by Meyer Rubin. Previously, the lower part of the terrace had been dated from mollusks as late Kansan to Illinoian. The material giving the 10,850 year date underlies what R. D. Miller believes to be the Brady soil of Schultz and Stout.[9] According to Miller and G. R. Scott, the newly determined date supports placing the Brady soil development in post-Two Creeks time.

Ground-water recharge

In the Frenchman Creek basin above Palisade, Nebr., W. D. E. Cardwell and E. D. Jenkins have determined that the rate of annual recharge to the ground-water reservoir (principally the Ogallala formation) is 0.9 inch out of a total average annual precipitation of 19.5

[9] Schultz, C. B., and Stout, T. M., 1948, Pleistocene mammals and terraces in the Great Plains, *in* Colbert, E. H., ed., Pleistocene of the Great Plains: Geol. Soc. America Bull., v. 59, p. 570.

inches. This amounts to about 220,000 acre-feet of water annually, which is considerably more than the present rate of pumping. In Washington County, Colo., H. E. McGovern has found that the annual recharge to the Ogallala formation is about 1 inch, which amounts to about 20 times the present rate of pumping. In Hamilton County, Nebr., where the annual precipitation is about 24 inches, C. F. Keech has determined that the recharge to the Pleistocene sand and gravel comprising the aquifer in that area is 1.4 inches.

According to C. F. Keech (1961) the application of surface water for irrigation along the Platte Valley below McConaughy Reservoir in Nebraska has caused an abrupt rise in ground-water levels from Lincoln County to Kearney County. Keech reports that the rise in water level exceeds 50 feet in one area in Phelps County and that the ground-water divide between the Platte and Republican Valleys has shifted southward several miles as a result of the rise.

Ground-water storage

In the Frenchman Creek basin above Palisade, Nebr., W. D. E. Cardwell and E. D. Jenkins calculate that the Ogallala formation contains about 81,000,000 acre-feet of ground water in storage. This is about 3 times the capacity of Lake Mead—the largest man-made lake in the United States. W. G. Hodson and K. D. Wahl (1960) report 1,200,000 acre-feet in storage in the Ogallala in northern Gove County, Kans. C. F. Keech reports about 9,000,000 acre-feet in storage in Pleistocene deposits in Hamilton County, Nebr.—enough to form a lake 26 feet deep over the entire county.

Buried channels

Buried channels of sand and gravel that are capable of yielding large quantities of water to wells have been located by geologic mapping and by test drilling in eastern Colorado and southeastern Wyoming. A deep narrow gravel-filled channel has been reported by D. A. Coffin in the upper reaches of Big Sandy Creek valley above Limon, Colo., and a major buried channel along the Arkansas Valley having a depth of more than 200 feet in places has been traced by P. T. Voegeli in Prowers County. In the Wheatland area in southeastern Wyoming, E. P. Weeks reports that additional drilling has revealed the presence of coarse channel deposits of sand and gravel within the finer materials characteristic of the Arikaree formation in that area. Irrigation wells that penetrate the coarse materials generally will yield 50 to 100 percent more water than the wells that penetrate only the finer materials.

Hydrogeology of Denver metropolitan area

G. H. Chase and J. A. McConaghy have found that the principal recharge area for the Arapahoe formation in the Denver basin is in the southern part of the basin and that the water moves into the formation through a part of the Dawson arkose. They report that development of scattered pumping centers coincident with the growth of the metropolitan area has created numerous cones of depression in the piezometric surface and a gradual expansion of the area of declining pressure heads in wells tapping the formation. Heads have recovered somewhat in the downtown area in the center of the 77-year-old cone of depression.

Chase and McConaghy also report the discovery of significant new aquifers in the Dawson arkose in some parts of the area. Some aquifers in the Dawson arkose yield water high in radon. Inversions of geothermal gradients occur between the Fox Hills sandstone and the Laramie formation, and also between the Laramie formation and the Arapahoe formation—Dawson arkose.

Relation of ground-water quality to bedrock

In the High Plains in parts of Cheyenne and Kiowa Counties, Colo., A. J. Boettcher has found that the quality of the water in the Ogallala formation differs according to the bedrock beneath the Ogallala. Where the Ogallala is underlain by the Smoky Hill marl member of the Niobrara formation, the ground water has a significantly higher concentration of sulfate and chloride than where it is underlain by the Pierre shale.

Ground-water development in New Mexico

Data collected by H. O. Reeder and others (1960a) indicate that as of 1956, 855,000 acres of land were under irrigation in New Mexico. Of this area, 440,000 acres were irrigated with ground water alone, 130,000 acres with a combination of ground water and surface water, and 285,000 acres with surface water alone. The irrigation with ground water involved the pumping of 1,320,000 acre-feet of water with the result that ground-water levels reached record lows in most areas except in parts of the Roswell basin and the Carlsbad area.

Distribution of moisture in soil and near-surface tuff

In conjunction with work on the Pajarito Plateau, N. Mex., for the Los Alamos Scientific Laboratory, J. H. Abrahams, Jr., J. E. Weir, and W. D. Purtymun (Art. 339) have shown that little, if any, water percolates through the soil mantle into the underlying rock. Using a neutron-scattering probe, they determined during a 99-day infiltration experiment that the moisture content of the soil decreased with depth from a maximum of about 38 percent by volume in the B zone to less than 4 percent within a foot of the surface of the underlying tuff. Water apparently was perched on the C zone and the moisture content within the B zone approached saturation.

COLORADO PLATEAU PROVINCE

Most of the geologic studies on the Colorado Plateau have been undertaken to aid in the search for uranium, but may have application to petroleum exploration. Most of the hydrologic studies have been undertaken to aid in locating supplies of potable water for the small communities in the area. This work contributes to a broader understanding of the regional geology and hydrology. Some of the findings of regional significance made during the fiscal year 1961 are summarized below. Results of work on mineral deposits in the region are reported on pages A–6 to A–7, and the results of work on geochemical prospecting are reported on page A–95.

Stratigraphy

Several geologists have reported new information on the stratigraphic relations of rocks of late Paleozoic and Mesozoic ages on the Colorado Plateau. Study of a small but good collection of vertebrate fossils by G. E. Lewis and P. P. Vaughn permits correlation of the upper part of the Cutler formation near Placerville, Colo., with the Wichita group of Texas (Wolfcamp) and parts of the Autunian and Rotliegende of western Europe, all of Early Permian age. Of interest in connection with the correlation of Permian strata are the dominant directions of dip of the foreset beds in the thick crossbedded sandstones of the south-central part of the plateau province. C. B. Read and A. A. Wanek (Art. 206) report that there are two preferred directions: (a) southeast to east in the Meseta Blanca sandstone member of the Yeso formation (Zuni Mountains), the lower part of the DeChelly sandstone (Defiance Plateau), and the Cedar Mesa sandstone member of the Cutler formation (Monument Valley); and (b) south to southwest in the Glorieta sandstone (Zuni Mountains), the upper part of the DeChelly sandstone (Defiance Plateau), DeChelly member of the Cutler formation (Monument Valley), and Coconino sandstone (near Holbrook and Winslow, Ariz.).

In Triassic rocks studied by F. G. Poole (Art. 199), dip orientation of cross strata record a shift of the regional drainage direction from northwesterly in Moenkopi and early Chinle time to southwesterly during deposition of the upper part of the Chinle, Kayenta, and upper part of the Moenave formations.

Age assignments of formations of the Glen Canyon group have been revised by G. E. Lewis, J. H. Irwin, and R. F. Wilson. The new assignments, adopted for use by the Geological Survey, are as follows:

Navajo sandstone—Jurassic and Triassic(?)
Kayenta formation—Triassic(?)
Moenave formation—Triassic(?)
Wingate sandstone—Triassic

The Navajo sandstone is reported by J. C. Wright to thin to zero on salt anticlines in eastern Utah and western Colorado, to thicken to as much as 700 feet in the intervening synclines (more than twice the normal regional thickness), and to extend in a continuous thinned belt northwesterly along the Cane Creek anticline to Bartlett Flat, 12 miles beyond the Colorado River.

According to L. C. Craig, a sandstone like the uranium-bearing "Jackpile sandstone" is present at the top of the Morrison formation in the eastern part of the San Juan Basin, and at Bernalillo and Santa Fe, N. Mex., and may be present as far east as Las Vegas, N. Mex.

R. A. Cadigan reports that the sandstone of the uranium-bearing Morrison formation (Late Jurassic) of the Colorado Plateau is composed of sodic tuff and ash, quartz, and sodic feldspar derived from the northwest; quartz and grains of silicified rocks derived from the west; quartz, fragments of silicified rocks and potassic tuff derived from the southwest; and quartz, potassic and sodic feldspar, potassic and sodic ash and tuff, and granite derived from the south and southeast. Igneous rock sources contributed 50 to 75 percent of the constituent detritus; extrusive igneous rocks alone contributed 30 percent or more.

New paleontologic evidence and stratigraphic correlations by C. H. Dane (1960a) suggest that much of the so-called Dakota sandstone of the eastern San Juan Basin may be of Late Cretaceous age, and therefore younger than the Dakota of northeastern New Mexico, which is entirely of Early Cretaceous age. The two areas may have been separated by an erosional barrier 15 to 25 miles wide extending southward along the 106° meridian toward central New Mexico.

Dane also calls attention to bentonite beds clustered near the horizons of lithologic changes from Dakota sandstone to Graneros shale, from Graneros to Greenhorn limestone, and from Greenhorn to Carlile shale. The bentonite beds may be widely useful in establishing regional correlations. They also suggest that more concentrated volcanic activity coincided with the epeirogenic or climatic changes that produced the changes in lithology at formation boundaries.

Paradox basin

J. E. Case and H. R. Joesting (Art. 393) report aeromagnetic and gravity anomalies that indicate major northeast structural trends transverse to the dominant northwest trend of the late Paleozoic and Laramide structure of the Paradox basin and Uncompahgre uplift. The most prominent of the inferred basement structures are two inferred faults that cross the Monument upwarp and Blanding basin and bound a zone of low density and generally low magnetization 20 miles wide and 50 miles long. Other northeast-trending structures parallel the Colorado River near Moab and Cisco, Utah, and another extends from the La Sal Mountains to Gateway, Colo. The intrusive rocks of the Abajo and La Sal Mountains lie at the intersections of northeast- and northwest-trending basement structures.

Potash-bearing salts of the saline facies of the Paradox member of the Hermosa formation are about to be developed commercially. R. J. Hite (Art. 337) reports that the saline facies extends over approximately 11,000 square miles, two-thirds of which is underlain by potash salts. The saline facies consists of 29 evaporite cycles of carbonate, gypsum, and salt deposits, of which about 18 contain potash salts and 11 contain potentially valuable potash deposits from 1,700 to 14,000 feet below the surface. At present these deposits are considered to be minable only in the salt anticlines where they lie at the shallower depths. Recent exploration has been concentrated on nonintrusive folds, such as the Cane Creek anticline; information concerning the intrusive folds is still meager.

Studies by E. R. Landis, E. M. Shoemaker, and D. P. Elston (Art. 197) demonstrate that growth of the Gypsum Valley salt anticline took place between Middle Pennsylvanian and Late Cretaceous time.

Geomorphology and physiography

Studies in northeastern Arizona by M. E. Cooley and J. P. Akers (Art. 237) show that four cycles of erosion, representing about 4,000 feet of downcutting, occurred throughout Miocene, Pliocene, and Pleistocene time in the Little Colorado drainage system of Arizona and New Mexico. Contours on the oldest surface at the base of the Bidahochi formation show that an entrenched, integrated drainage system of the ancestral Little Colorado River flowed generally westward and northwestward during Miocene and Pliocene time.

Unaweep Canyon, a wind gap in Precambrian crystalline rocks of the Uncompahgre plateau, is interpreted by S. W. Lohman (Art. 60) to have been carved by the ancestral Colorado River and to have been abandoned after successive captures of the ancestral Colorado and Gunnison Rivers by a subsequent tributary cutting in soft shale around the nose of the northwestward-plunging Uncompahgre arch.

Hydrologic studies

Geologic and ground-water studies in the Colorado Plateau by D. A. Phoenix (Art. 195) classify the thick and varied sequence of rocks into 7 hydrogeologic units. Unit 1, alluvium of Quaternary age, yields water in places. This water is locally contaminated by the activities of man. Units 2, 3, and 5 are shales of Tertiary, Cretaceous, and Triassic ages, which cover more than one-half the region; they are mostly nonwater-bearing, and yield large amounts of dissolved solids and clay. Unit 4, sandstones of Triassic and Jurassic ages, yields water suitable for many uses, but the sandstones also yield large amounts of sandy sediment. Unit 6, mostly limestone and shale of Paleozoic age, locally yields significant amounts of brine but in other places is similar to unit 4. Unit 7, igneous rocks of Tertiary age and basement rocks of Precambrian age, yields excellent water; these rocks crop out mostly in mountainous areas.

In the Grants-Bluewater area, Valencia County, N. Mex., the Glorieta sandstone and the overlying San Andres limestone, of Permian age, are the principal aquifers. Alluvium and interbedded basalt of Quaternary age form an aquifer of secondary importance. E. D. Gordon reports that most large-capacity wells in the area pump from the San Andres, and where the hydraulic pressure in the San Andres has been decreased, water has moved from the Glorieta into the San Andres. The use of ground water between 1950 and 1957 was stabilized at about 13,000 acre-feet per year. Withdrawal of ground water has caused water levels to decline 40 to 45 feet north of Bluewater Village, and 18 to 20 feet from Bluewater Village southeast to near Grants. Yields of irrigation, industrial, and municipal wells range from 500 to 2,200 gpm. Generally, the water is suitable for irrigation, although the salinity is high locally. At some places the sulfate concentration is high enough to impart an objectionable taste to the water.

In the Ashley Valley oil field, Uintah County, Utah, R. D. Feltis and H. D. Goode (Art. 184) report that the comparatively fresh oil-field water, which contains only 500 to 2,000 ppm total solids, is being used for irrigation. This use is made possible by the fact that deleterious components of the water are neutralized by components of the soil. The oil and associated water are derived from the Weber sandstone of Pennsylvanian age. The water drive for the oil is probably sustained by surface recharge in outcrop areas north and east of the field.

According to S. W. Lohman, the principal artesian aquifers in the Grand Junction area, Colo., are the

Entrada sandstone of Jurassic age and the Wingate sandstone of Triassic age. Recharge to them occurs a short distance southwest of town where they are exposed along the Redlands fault and associated monoclines. The artesian wells normally yield 5 to 25 gallons per minute. Between Grand Junction and the outcrop area, the ground water is of a sodium bicarbonate type excellent for domestic use. Where the water-bearing beds are deeper and farther from the outcrop, as is the case northeast of Grand Junction, the water contains more dissolved solids and is therefore less useful.

Detailed lithologic studies of Navajo sandstone in the Copper Mine-Preston Mesa area, Coconino County, Ariz., by N. E. McClymonds (Art. 321) show that upwarping accompanied deposition of the Navajo sandstone. Ground water is absent on the higher parts of the upwarp but occurs on its flanks. Locally it occurs near the crest, in a tongue of the Navajo sandstone underlying a tongue of the Kayenta formation.

J. P. Akers and P. E. Dennis report that additional ground water for the town of Flagstaff, Ariz., may be obtained from glaciofluvial sediments in the Inner Valley on San Francisco Mountain, Coconino County, and from permeable zones along several large normal faults.

Injection tests at the Bluewater uranium mill of the Anaconda Co. at Grants, N. Mex., indicate to S. W. West that sediment-free mill affluent can be charged into the lower part of the Yeso formation through an 8-inch well at the rate of more than 380 gpm but less than 1,000 gpm. Studies of ground water in alluvium along the Colorado and Gunnison Rivers in western Colorado by D. A. Phoenix show that this water locally contains between 20 and 40 ppm nitrate, expressed as NO_3. The nitrate probably originates from nitrogenous fertilizers used in farming.

BASIN AND RANGE PROVINCE

Geologic and hydrologic investigations in progress in the Basin and Range Province have yielded important new information in structural and stratigraphic geology, volcanology, and hydrology as summarized below. Additional information is given on other pages as follows: mineral deposits, pages A-1 to A-8; paleontology, pages A-59 and A-60; geophysical work, pages A-69 to A-71; evaporite deposits, page A-76; work at the Nevada Test Site, pages A-90 to A-91; geochemical prospecting, page A-95; Pleistocene lakes, page A-11; and Pleistocene climate, page A-87.

Thrust faults in Nevada and Utah

In central and eastern Nevada, interpretations of the complex thrust fault problems depend in large part upon interpretations of stratigraphic relations. R. L. Erickson and A. P. Marranzino, working in conjunction with Harold Masursky, have found evidence that the three previously defined facies of Paleozoic rocks in the region—the eastern, transitional, and western facies—have distinctive metal contents. Preliminary results suggest that western facies siliceous rocks are rich in metals, particularly in vanadium, copper, barium, and titanium, whereas eastern facies rocks are poor in metals. This evidence suggests that rocks in the Cortez quadrangle, Nevada, previously thought to be eastern facies and part of the lower plate of the Roberts Mountain thrust fault, may be transitional or western facies and part of the upper plate.

In the southern Diamond Mountains of eastern Nevada, D. A. Brew (Art. 191) has found that the Chainman shale on the upper plate of the Bold Bluff thrust fault is 3,500 to 4,000 feet thick and is composed of siltstone, claystone, and sandstone; whereas on the lower plate it is 2,500 feet thick and is composed of black shale.

Mapping by T. B. Nolan and C. W. Merriam in the Lone Mountain area of eastern Nevada shows that the principal structural feature is a window. The main mass of Lone Mountain is composed largely of eastern facies carbonate rocks ranging in age from Ordovician to Middle Devonian. Pediments on the flanks of Lone Mountain reveal rocks of the upper plate, including graptolitic shale and chert belonging to the Vinini formation of Ordovician age, associated with fusulinid-bearing strata of the Garden Valley formation of Permian age.

An analysis by M. D. Crittenden, Jr., (Art. 335) of the thicknesses of three groups of Paleozoic rocks in northern Utah indicates displacements of about 40 miles across a belt of overthrusts, including the Bannock, Willard, Charleston, and Nebo faults. The overriding blocks moved relatively eastward. The analysis does not rule out even larger displacements. In contrast, in the Kings River Range area of northwestern Nevada, C. R. Willden (Art. 192) has found thrust fault relations that indicate westward overriding of at least 40 miles, so that nonmetamorphosed rocks of Permian to Middle Triassic age rest on metavolcanic rocks of probable Permian or older age.

In southwestern Utah, D. M. Lemmon and H. W. Sundelius mapped the upper plate of the Frisco thrust from Frisco Peak northeast for 21 miles. Six windows of lower plate rocks of late Cambrian and Ordovician ages are exposed in the San Francisco Mountains as far as 9 miles northeast of Frisco Peak, but none was observed farther north in the Beaver Mountains.

Other structural features

R. K. Hose has found through detailed mapping that the Confusion Range of western Utah was the site of a large structural trough at the end of the late Mesozoic orogeny. He has determined that the flanks of the trough had average slopes of as much as 19 degrees, and he believes that this relief coupled with contrasts in competency of rocks involved accounts for the different tectonic styles displayed by rocks in the area. Relatively competent lower Paleozoic rocks are characterized by broad open folds and homoclines, whereas incompetent upper Paleozoic and Triassic rocks show complex disharmonic folds and thrust faults.

Recent studies of ancient Lake Bonneville shore lines in western Utah by Crittenden (1960) support G. K. Gilbert's conclusion of 1890 that the increase in elevations of these shore lines since Pleistocene time is the result of isostatic rebound after unloading. The maximum deflection of 210 feet indicates that isostatic compensation for removal of the load is at least 70 percent of the theoretical maximum, and may be virtually complete.

A northward trending elongate dome about 40 miles wide and 80 miles long is centered roughly between the Snake and Deep Creek Ranges, Nev., according to structural analysis by H. D. Drewes (1960). The dome has been strongly modified by near-bedding-plane thrust faults and complex north-trending structures.

T. W. Dibblee, Jr. (Art. 82) has found that many of the northwest-trending high-angle faults of Quaternary age in the western Mojave Desert region show evidence of right-lateral displacement, in the same sense as the San Andreas fault. This type of displacement is indicated by the offset of contacts and fold axes, by east-trending drag folds associated with the faults, and by north-trending tension fractures.

Geologic mapping by G. I. Smith (1960) along the Garlock fault, southeastern California, has shown that two large dike swarms that crop out 40 miles apart on opposite sides of the fault are similar and probably represent offset segments of the same swarm. The swarms were probably intruded during late Mesozoic time, just before movement of the fault began, and the present separation of 40 miles approximates the total left-lateral displacement on the fault.

Studies of Cambrian and Precambrian rocks

Recent geologic mapping by M. H. Krieger (Art. 207) in the northern end of the Galiuro Mountains of southeastern Arizona has shown that rocks formerly called Troy quartzite and considered to be of Cambrian age actually include two units, one of Precambrian and the other Cambrian age, separated by a major unconformity. The unit of Precambrian age, to which the name Troy quartzite is now restricted, was intruded by diabase sills before deposition of the unit of Cambrian age, which includes the Bolsa quartzite and the Abrigo formation.

In central Arizona, A. F. Shride has found that an extensive karst topography was developed on dolomite of the Mescal limestone of Precambrian age, both before and during deposition of the overlying Troy quartzite. The dolomite was thoroughly silicified during the period of weathering, and locally a highly ferruginous regolith was formed.

In sandstone overlying the Precambrian in the Mingus Mountain-Jerome area, central Arizona, heretofore regarded as Tapeats(?) formation (Cambrian) by some geologists and as basal Devonian by others, Curt Teichert discovered a bed crowded with **U**-shaped burrows of the *Corophioides* type. Occurrence of these trace fossils removes doubts as to the correlation of this sandstone with the Tapeats, because they occur abundantly in undoubted Tapeats sandstone of Juniper Mesa, the Chino Valley, and the Grand Canyon.

A. R. Palmer has found from a study of Lower Cambrian faunas and their distribution that the names Stirling and Prospect Mountain for Lower Cambrian quartzites of the Great Basin are not merely different geographic designations for parts of a simple eastward time-transgressive quartzite series. The Prospect Mountain quartzite is at least in part a regressive quartzite with its thin western edge represented by the Zabriskie quartzite member of Hazzard[10] of the Wood Canyon formation, several thousand feet stratigraphically above the Stirling quartzite.

New data on Cretaceous rocks

Along the east side of the Cortez Range, Pine Valley quadrangle, Nevada, a sequence of nonmarine rocks mapped by J. F. Smith, Jr., and K. B. Ketner and previously considered to be of Tertiary(?) age, is now known on the basis of studies of plant and pollen to be of Cretaceous age. Plants collected from these beds have been dated as Cretaceous by J. A. Wolfe, and pollen have been dated as Early Cretaceous or early Late Cretaceous by E. B. Leopold. The sequence rests on volcanic rocks which must, therefore, be of Cretaceous age or older.

In the southern extension of the Piñon Range, 10 miles east of the above locality, nonmarine rock in a small area contains ostracodes which have been determined by I. G. Sohn to be of probable Early Cretaceous age.

Emplacement and age of intrusive bodies

The Climax stock, Nevada Test Site, Nye County, has been found by F. N. Houser and F. G. Poole (Art.

[10] Hazzard, J. C., 1937, Paleozoic section in the Nopah and Resting Springs Mountains, Inyo County, Calif.: California Jour. Mines and Geology, v. 33, no. 4, p. 273–339.

73) to be made up of an older granodiorite and a younger quartz monzonite. Ages of 230 and 330 million years have been determined by the lead-alpha method for the quartz monzonite. The lesser age is in better accord with geologic evidence. (See also p. A–91.)

Tertiary volcanic rocks and calderas

Aided by criteria established largely by R. L. Smith, (1960a, b) several large, heretofore unknown calderas have been recognized in the Basin and Range Province. In southwestern Nevada, west of Beatty, H. R. Cornwall and F. J. Kleinhamphl (1960a, b) have delineated the Bullfrog Hills caldera, which is about 15 miles in diameter. Another probable caldera, about 10 miles in diameter, occupies Yucca Mountain to the east of Beatty. Northeast of these two, in the vicinity of Timber Mountain, a large caldera has been recognized through work by F. A. McKeown, E. N. Hinrichs, P. P. Orkild, and others in collaboration with R. L. Smith. This caldera measures at least 18 miles in diameter and is responsible for rather conspicuous ringlike topographic features around Timber Mountain. Oligocene(?) welded tuffs about 8,000 feet thick were found by Harold Masursky (1960) in the northern Toiyabe Range, Nev., in a fault-bounded trough, perhaps a volcano-tectonic depression, about 10 miles wide and 50 miles long in an east-west direction.

D. R. Shawe (Art. 74) has discovered that two rhyolitic rocks of Tertiary age in the Egan Range of eastern Nevada are superficially similar but are chemically and petrographically distinct, and probably were not derived from the same magmatic source. One, an intrusive rhyolite confined principally to a volcanic neck about one mile in diameter, contains 73.5 percent silica and 13.6 percent alumina. The other, a welded tuff, contains 69.7 percent silica and 14.1 percent alumina as well as several times as much iron oxide, magnesia, lime, and titania as the intrusive rhyolite, and less soda and potash.

In the Klondyke quadrangle, Arizona, F. S. Simons has found that the Copper Creek breccia pipes are lined along a vaguely defined northwest trend that may reflect a buried elongate body of biotite latite.

Geologic mapping by J. R. Cooper in the Twin Buttes quadrangle and other parts of southeastern Arizona has established that a distinctive volcanic rock known locally as the "turkey-track porphyry" occurs as flows and dikes in at least 10 neighboring mountain ranges. At one place the rock is enclosed in beds of probable early Miocene age. The rock ranges in composition from olivine-augite-plagioclase porphyry to hypersthene-augite-plagioclase porphyry.

D. W. Peterson (Art. 322) reports that the degree of flattening of pumice fragments in an ash-flow sheet near Superior, Ariz., increases progressively downward. This indicates that ash flows erupted in such rapid succession that the sheet formed as a single cooling unit. The difference in flattening ratios on opposite sides of faults can be used to estimate stratigraphic throw.

Quaternary history

Ronald Willden and D. R. Mabey (1961) have discovered giant dessication cracks in the playa deposits of the Black Rock Desert and other basins of western Nevada. The cracks form large polygons, several hundred feet on a side, and probably resulted from the desiccation to unusual depths of playa sediments, thus suggesting a period of years of extreme dryness.

R. B. Morrison (Art. 330) has suggested that the boundary between the Pleistocene and Recent (Holocene) in the great Basin region be placed at the top of a distinctive soil (the post-lake Lahontan soil), the type area of which is the Carson Desert, Nev.

East of the Funeral Mountains, Calif., C. S. Denny (Art. 323) has mapped landsides, in large part highly brecciated sheets of limestone (megabreccia), that moved along gullies out onto the pediment.

Ground-water occurrence and movement in pre-Tertiary rocks

Studies of ground-water systems in intermontane basins of the Basin and Range Province indicate that (a) ground-water moves locally from one intermontane basin to another through pre-Tertiary bedrock formations; (b) pre-Tertiary bedrock may play an important role in ground-water circulation within a closed or nearly closed basin; and (c) Tertiary formations underlying Quaternary alluvium in valleys have an important role in the storage, recharge, and development of ground water.

Studies in the Nevada Test Site by I. J. Winograd show that the regional water table is generally deep below the Quaternary alluvium and commonly is in the Oak Spring formation, which underlies the alluvium. The slope of the regional water table in the Oak Spring formation is very gentle, and ground-water movement is slow. From observations of the discharge of Ash Meadow and other springs in the area southwest of the Nevada Test Site, together with water-level and chemical data from wells in adjoining areas, O. J. Loeltz (1960b) has concluded that ground water moves in pre-Tertiary formations between valleys.

T. E. Eakin reports that the White River drainage system of eastern Nevada contains numerous springs that issue from Paleozoic limestone. These occur in four general areas—between Preston and Sunnyside, in Pahranagat Valley, near the mouth of Arrowhead

Canyon, and northwest of Moapa. The springs in Pahranagat Valley and near the mouth of Arrowhead Canyon discharge about 35 cfs (cubic feet per second) and 40 to 45 cfs, respectively. These volumes are relatively large as compared with the drainage areas and suggest that considerable inflow occurs through pre-Tertiary bedrock from outside the topographic drainage area. Some of the inflow may come from Long Valley, which is 30 to 40 miles northwest of the headwater area of White River Valley. A substantial part of the ground water in Long Valley apparently is being discharged through pre-Tertiary bedrock, and geologic trends and potential hydraulic gradients suggest that it is moving generally southward toward the White River Valley.

Hydrogeochemistry

Philip Cohen has concluded that the uranium content of the waters of Truckee Meadows, near Reno, Nev., is not by itself an important aid in evaluating the hydrogeochemistry of the area. Forty-seven samples of water were analyzed for uranium and many other chemical constituents. It was found that (a) uranium content tends to increase as the bicarbonate-carbonate concentration increases; (b) thermal chloride-rich waters associated with Steamboat Springs are relatively deficient in uranium; and (c) some waters high in sulfate are relatively rich in uranium, but others are not. The complex geology, the complex interrelationships among chemical and radiochemical constituents of the waters, and the wide variations in concentration, all affect the movements of uranium.

Specific yield of sediments

Philip Cohen (Art. 164) reports that the specific yields of fine-grained sediments from the Humboldt River Valley in the vicinity of Winnemucca, Nev., are exceptionally high, due in part to the effects of secondary porosity. The mean specific yield of 209 samples is 21 percent. The specific yields were determined by the centrifuge-moisture-equivalent method. The values for specific yield are useful for estimating ground-water storage capacity but cannot be used for evaluating short-time changes in ground-water storage.

Floods and mudflows

Studies in Utah under the direction of V. K. Berwick indicate that in drainage basins where the runoff is principally snowmelt the ratio of the mean annual flood to the 50-year flood is about 1 to 2. In basins where runoff is from cloudbursts, the ratio is about 1 to 6. The data also suggest that highest rates of precipitation occur at intermediate rather than higher altitudes in the Basin and Range Province. As the long intervals between cloudburst floods provide time for the accumulation of soil and debris, high-intensity rains of short duration may result in mudflows.

A mudflow that occurred in Kings Canyon, on the east slope of the Sierra Nevada near Carson City, Nev., on July 30, 1960, was estimated by L. J. Snell to contain about 320,000 cubic feet (7.4 acre-feet) of material, including boulders 2 feet or more in diameter, and short logs as much as 2 feet in diameter. Peak discharge probably did not exceed 150 cfs. A cloudburst within a drainage area of 1.2 square miles and between altitudes of 5,300 and 8,500 feet, caused the mudflow.

COLUMBIA PLATEAU AND SNAKE RIVER PLAINS

Studies of stratigraphy and geologic history in the Columbia River Plateau and Snake River Plains are concentrated in the John Day region of Oregon and the Snake River Plains of southern Idaho. Studies of water resources include work on discharge in the Columbia River basin, quality of ground water in the eastern Snake River Plains, and ground-water hydrology of basalts in several parts of the Columbia Plateau and the Snake River Plains. Other hydrologic work in the region is summarized on pages A–39 to A–40, A–92, and A–93 to A–94.

Laumontite stage metamorphism of Upper Triassic rocks, Aldrich Mountains, Oregon

In a comprehensive study of the mineralogy of the thick Upper Triassic sequence of bedded rocks in the Aldrich Mountains of Oregon, C. E. Brown (Art. 201) found an authigenic mineral assemblage characteristic of the zeolite metamorphic facies. The mineralogic observations support the inference previously drawn from field studies that these rocks were deformed during deposition in Late Triassic time. Most of the rock types in the section (graywacke, shale, mudstone, tuff, pillow lava, and volcanic graywacke) contain authigenic albite, quartz, chlorite, sphene, epidote, and leucoxene, but the rock types all or partly of volcanic origin are characterized by laumontite, prehnite, pumpelleyite, and celadonite. These minerals grew in an environment of increased pressure and temperature that possibly resulted from depth of burial and (or) tectonic folding not long after deposition of the rocks. Stocks of Cretaceous age had notable local contact effects, but had little regional influence on the assemblage of authigenic minerals.

Facies changes in the John Day formation

In the vicinity of Ashwood, Oreg., a section of the John Day formation described by D. L. Peck (Art. 343) is about 4,000 feet thick and is made up dominantly of more or less welded ash flows, lava flows, and abundant beds of lapilli tuff, in marked contrast to the fine tuff and tuffaceous claystone of the type section about 50 miles east at Picture Gorge. These newly described rocks are in or near the area of their source vents.

Volcanic ash falls used as stratigraphic marker beds

H. A. Powers and H. E. Malde (Art. 70) have used chemical and mineralogical techniques to identify beds of volcanic ash in widely separated exposures of sedimentary deposits in the western Snake River Plain, so as to correlate stratigraphic sections of dissimilar lithology and to determine amounts of basin deformation. For example, chemical comparisons by Powers (Art. 111) show that the amounts of chlorine and fluorine in different ash deposits are different in most examples, although the amounts are nearly equal in various samples from the same ash deposit.

Gravity anomalies

The study of gravity in the western Snake River Plains now extends from the Oregon line eastward to Twin Falls, Idaho. D. P. Hill, H. L. Baldwin, Jr., and L. C. Pakiser (Art. 105) suggest that 3 elongated en echelon gravity highs found under the western part of the plain may be due in part to basalt-filled major fissures in the crust.

New data on the age of the Columbia River basalt

K. E. Lohman has determined that the upper part of the Columbia River basalt (Yakima basalt) is of early Pliocene age on the basis of diatoms collected by A. C. Waters. This confirms previous determinations based on fossils of vertebrates and fresh-water mollusks.

Southward transgressive overlap of the basalt

Near the southern margin of the Columbia River basalt plateau, in the Monument quadrangle, Oregon, the persistent occurrence of basaltic breccia and related rock-forms at the base of the basalt on dissected rocks of the John Day formation is ascribed by Ray E. Wilcox to flow-by-flow encroachment up valleys and into lakes ponded by preceding flows.

Landforms of Pleistocene age in the Snake River Plains

H. E. Malde (Art. 71) finds that sorted nets, circles, and stripes occur on the dissected surfaces of various deposits of middle Pleistocene and older age in the western Snake River Plains; these patterned features resemble solifluction features of polar regions. Because this patterned ground is not found on the surface of deposits of late Pleistocene or younger age, it is considered to be a fossil landform that developed under a former colder climate.

Pleistocene American Falls lake and the Michaud gravel

A study of the Michaud gravel near American Falls, Idaho, by D. E. Trimble and W. J. Carr (Art. 69) shows it to be a delta deposited in a Pleistocene American Falls lake by a large stream entering the lake through the Portneuf canyon. This ancient stream is G. K. Gilbert's Bonneville River, the outlet of Pleistocene Lake Bonneville. Carbon-14 analyses show that the Michaud gravel delta is more than 30,000 years old.

Other Pleistocene drainage changes

A study by D. W. Taylor (1960) may supply further evidence that the Snake River system was joined to the Columbia River system comparatively recently, and that the Snake River formerly drained other areas in Oregon, California, and Nevada. Taylor reports that Pliocene and Pleistocene remains of *Pisidium ultramontanum* Prime, a freshwater clam that lives in northeastern California and south-central Oregon, occur in the rocks of the Snake River Plain as far upstream as southeastern Idaho. This occurrence, together with the distribution of several other relict mollusks and fishes, indicates former drainage connections along a chain of basins extending from Walker Lake in western Nevada across Eagle Lake and the upper Pit River, Calif., to Klamath Lake in Oregon; thence across Fossil Lake and the Malheur Basin, Oreg., to the Snake River Valley; and through Gentile Valley and Bear Lake, Idaho, to Utah Lake in the Lake Bonneville Basin.

Basin discharge studies

K. N. Phillips has observed that the water levels of Davis Lake and East Lake in the Deschutes River basin were higher in 1957 and 1958 than they have been in many years. Trees 200 years old were being drowned in 1957 by the high waters of Davis Lake, and, in 1958, trees 50 years old were being drowned by high waters of East Lake. Runoff in the Oregon part of the Columbia Plateau has been considerably above normal during the period from 1942 to 1958.

A method for predicting monthly and seasonal streamflow during the low-flow periods for many tributaries of the Columbia River has been devised by C. C. McDonald and W. D. Simons. The method takes into account data on base-flow characteristics, historical runoff, and selected levels of probability.

In the Snake River basin of Idaho, studies by C. A. Thomas and others show that the magnitude of natural flood runoff at selected frequencies at any site may be forecast within reasonable limits by statistical extension of data gathered on previous floods. The statistical method uses a formula that integrates locally derived factors for drainage area, precipitation, and geographic conditions.

Cloudburst floods on August 20, 1959, from recently burned-over slopes near Boise, Idaho, were found by W. I. Travis and associates to have produced runoff as great as 5,380 cfs per square mile from a drainage area of 0.39 square mile. The volume of the flood reaching the lowlands was approximately 500 acre-feet, and the debris deposited on the lowlands was about 200,000 tons, or one ton of debris for each 3.4 tons of fluid. The transporting flood retained approximately the fluidity of water despite the mud-flow appearance of the deposited debris.

Quality of ground water

E. H. Walker has identified several distinct types of ground water beneath the eastern part of the Snake River Plains. These are (a) partly thermal waters, mainly of the sodium carbonate type but with some calcium-magnesium-bicarbonate, sodium chloride, and sulfate varieties, (b) meteoric waters, which are mainly calcium-magnesium-bicarbonate varieties and have smaller amounts of dissolved solids progressively toward the northern side of the plains, and (c) ground water mixed with returned irrigation waters which contain larger amounts of dissolved solids than the meteoric waters.

Studies of uranium and radium in ground water in the Pacific Northwest are summarized on page A–83.

Ground water in basalts

The rubble present at the base and top of basalt flows is locally thick and continuous; such layers are important aquifers for the movement of ground water in the Columbia Plateau and Snake River Plain. Field studies by M. J. Grolier, utilizing data accumulated during previous investigations, show that several such major aquifers can be identified and traced throughout a large area of central Washington in the region of the Grand Coulee. Permeable basalt layers that dip beneath the water table in Cow Valley of the Malheur River basin afford high yields to wells (Foxworthy, Art. 203) and may be present and unused in many other places. Such layers are preferable to the overlying permeable alluvium as a source of water because well construction is simpler, yields are higher, and the water is free of sand.

R. C. Newcomb (Art. 88) found that synclines in the Columbia River basalt are the major areas of ground-water accumulation, and that sharp folds and strike faults are barriers that trap substantial reservoirs of ground water.

In a study of the hydrology of radioactive waste disposal at the National Reactor Testing Station, Idaho, P. H. Jones (Art. 420) has found that important aquifers and sedimentary interbeds in the Snake River lavas can be identified and mapped locally by means of caliper and gamma-ray logs; and that warm, saline disposal waste-water can be traced in lateral extent by temperature and resistivity logs. Subsurface information compiled by E. H. Walker for wells at the testing station shows that the top 1,000 feet of the predominantly lava section contains interbedded sedimentary materials, largely in three zones. The position and extent of the sediments indicate they were deposited in lakes impounded by the extrusion of lavas to the southwest.

PACIFIC COAST REGION

Investigations in the Pacific Coast region are grouped for discussion into the following categories: (a) Washington, (b) Oregon, (c) Klamath Mountains and Coast Ranges of northern California, (d) coastal areas of central and southern California, (e) Sierra Nevada, and (f) hydrologic studies. Additional information pertinent to the region is summarized on other pages as follows: gold in California, page A–3; paleontologic studies, page A–60; geophysical studies, pages A–69 to A–70; and landslides in the Los Angeles area, page A–89.

Washington

Geologic mapping in King County by J. D. Vine and H. D. Gower and parallel studies of fossil plants by J. A. Wolfe (Art. 233) have distinguished seven floral zones that range in age from early Eocene to possible earliest Oligocene in the coal-bearing Puget group. Fossil plants have also been collected from the lower part of the overlying Keechelus andesitic series at scattered localities in the Cascade Range from Green River canyon, King County, south to Mount St. Helens. Floras from eight localities examined by Wolfe (Art. 232) are equivalent in age to the Keasey and Lincoln "stages" of the Oligocene. These floras and others from the Puget group indicate that the uppermost part of the Puget group in the Green River canyon area is correlative with the lowest part of the Keechelus farther south near Tacoma.

D. J. Stuart (Art. 248) finds a close correlation between gravity highs and basaltic volcanic rocks in western Washington. His bouguer anomaly map shows a continuous gravity high superimposed on the westward-opening U-shaped band of volcanic rocks around the Olympic Mountains; the map also shows very large negative anomalies near Seattle and Everett that indicate thick Tertiary sedimentary sections. Analysis of the anomalies suggests that the volcanic rocks, or associated dense crustal rocks, reach thicknesses of tens of thousands of feet.

Oregon

As part of a regional study of the stratigraphy and structure of Tertiary rocks in the Coast Range of Oregon, E. M. Baldwin has discovered a major structural basin on the lower Umpqua River near the town of Elkton. Near the center of the basin, rhythmically bedded sandstone of the middle Eocene Tyee formation, is overlain by several thousand feet of siltstone that has yielded abundant marine fossils of late middle or early late Eocene age. Overlying this siltstone with slight angular unconformity are plant-bearing beds of sandstone, largely of continental origin, that are tentatively assigned to the Coaledo formation of late Eocene age.

A detailed study of the marine mollusks of the Astoria formation of middle Miocene age in western Oregon by Ellen J. Moore supports the correlation of the Astoria with the Temblor formation in California ("Barker's Ranch" fauna). Rocks dredged from the Coos Bay channel have yielded a Miocene fauna equivalent in age to the Astoria fauna.

P. D. Snavely and H. C. Wagner (Art. 344) describe the widespread upper Oligocene gabbroic and alkalic sills that intrude Eocene sedimentary and volcanic rocks of the Oregon Coast Range. Granophyric gabbro and diorite are the principal species in a differentiated suite of rocks similar chemically to the Skaergaard, but most of the sills are more alkalic in composition and compare closely to Nockolds' average tholeiitic andesite.

A layer of basalt 45 to more than 315 feet thick that underlies alluvium in Cow Valley, Malheur County, Oreg., is fractured along faults and is an important source of water for irrigation. According to B. L. Foxworthy (Art. 203), excessive pumping of this aquifer during the period 1951 to 1960 led to a progressive lowering of the water table. His studies indicate that recharge to the drainage basin of about 60 square miles is about 5,000 acre-feet per year, which is about ⅔ of the yearly withdrawal.

Klamath Mountains and Coast Ranges of northern California

A geologic reconnaissance of the northern Coast Ranges and Klamath Mountains in California by W. P. Irwin (1960) shows that the Klamath Mountains comprise four concentric arcuate belts, concave to the east, that include rocks ranging from the Abrams mica and Salmon hornblende schists of pre-Silurian age to metavolcanic rocks and slate of the middle Upper Jurassic Galice formation. West of the Klamath Mountains are the northern Coast Ranges, composed chiefly of graywacke and shale of the Franciscan formation of Late Jurassic to Late Cretaceous age. (See also p. A-1.)

E. H. Bailey (1960) has described the Franciscan formation as an ensimatic eugeosynclinal deposit that consists 80 percent of graywacke, 10 percent of siltstone and shale, 8 percent of mafic rocks, and the rest of conglomerate, limestone, chert, and glaucophane and related schist. Although the Franciscan is dominantly unmetamorphosed, it includes scattered rocks of the zeolite (laumontite), "blueschist", and eclogite facies. On the basis of specific gravity determinations of over 1,000 specimens, W. P. Irwin (Art. 78) reports that the median specific gravity of sandstone in the Franciscan is 2.65, appreciably higher than the median specific gravity of sandstone in the Knoxville formation and formations of Cretaceous age in the Sacramento Valley. All specimens of graywacke in the Franciscan with a density above 2.71 contain minerals resulting from metamorphism, chiefly jadeite, pumpelleyite, and lawsonite. Assemblages of these and other minerals indicate that parts of the Franciscan have been subjected to high-pressure, low-temperature metamorphism of the "blueschist facies." These conditions require a load of at least 70,000 feet of sediments, which could be attained in a rapidly filling and rapidly subsiding basin. It is inferred that the "blueschists" must have been uplifted before a normal thermal gradient was established, as otherwise they would have been converted to greenschist.

Studies by C. W. Merriam (Art. 216) of faunas from marine Silurian and Devonian strata in the eastern Klamath Mountains indicate that the Gazelle formation is of Silurian and Early Devonian age, and is partly correlative with Silurian rocks at Taylorsville and probably correlative with the Copley greenstone and Balaklala rhyolite, which underlie the Middle Devonian Kennett formation.

Studies by G. D. Bath and W. P. Irwin of aerial- and ground-magnetic traverses across the northern Coast Ranges, Great Valley, and Klamath Mountains provinces of California show a close correlation between large positive anomalies and large bodies of ultramafic rock. The anomalies over ultramafic rock are comparable in amplitude and character to the anomaly that extends for more than 300 miles along the central part of the Great Valley, suggesting that the Great Valley anomaly is caused by a buried mass of ultramafic rock.

In a complexly faulted block along the boundary between the Sacramento Valley and the Coast Ranges, R. D. Brown, Jr., and E. I. Rich have found that strata previously regarded as Franciscan are sandstone and interbedded mafic volcanic rocks of the Knoxville formation.

Coastal area of central and southern California

A stable shoreline persisted in the area of the Caliente Range, Calif., from early to late Miocene time, and an exceptionally thick continuous sequence of highly fossiliferous intertonguing marine and continental strata was deposited. Several basalt flows in the sequence extend from marine to continental rocks, providing distinctive lithologic and time horizons. On the basis of faunal studies and detailed mapping in the eastern part of the Caliente Range, C. A. Repenning and J. G. Vedder (Art. 235) have correlated mammalian faunas representing three North American provincial ages (as defined by Wood and others) with marine mollusk faunas of Miocene age. The Arikareean (mammalian) age is at least in part correlative with the early Miocene as defined by marine mollusk faunas, and the upper limits of these two faunal ages are essentially identical. The Hemingfordian (mammalian) fauna is entirely equivalent to part of the middle Miocene marine mollusk fauna. The Barstovian (mammalian) fauna is in part correlative with middle Miocene and in part equivalent to probable late Miocene marine mollusk faunas. Clarendonian and Hemphillian mammalian faunas occur in the upper part of the continental strata, but equivalent Miocene and Pliocene marine beds are not known in the area.

In the western part of the Puente Hills, R. F. Yerkes has mapped a 10-mile-wide band of steeply plunging folds along the north side of the Whittier fault that, on physiographic evidence, has long been considered a strike-slip fault. The folds decrease in plunge from 75° in the west to about 35° in the east. Interpretation of the folds as drag folds along the fault suggests that right-lateral strike slip dominated at the western end of the fault, and reverse dip slip in the eastern part; in both places a net slip of about 15,000 feet is indicated.

Studies by J. G. Vedder of large assemblages of marine mollusks from the lowest emergent terrace in the San Joaquin Hills area, southern California, provide evidence of complex local paleoecologic conditions during late Pleistocene time. Between San Clemente and Corona del Mar vigorous upwelling locally cooled surface waters that were warmer than at present. Surface-water temperatures were even higher east of the present upper Newport Bay, in the protected eastern part of the ancestral Newport Lagoon. Mollusks from the West Newport oil field include species characteristic of various habitats and temperatures; this mixture suggests the effects of current transportation, incursions of fresh water, and reworking of older faunas.

Late Jurassic fossils have been identified from two localities in pre-granitic rocks in the Santa Ana and Santa Monica Mountains of California. In the Santa Ana Mountains, J. E. Schoellhamer and N. J. Silberling of the U.S. Geological Survey, and C. H. Gray of the California Division of Mines, collected ammonites from the Bedford Canyon formation that have been identified by R. W. Imlay as Callovian (early Late Jurassic) in age. The Santa Monica slate in the Santa Monica Mountains has yielded pelecypods identified by Imlay as species of *Buchia* of late Oxfordian to Kimmeridgian (middle Late Jurassic) age.

Sierra Nevada

Comparison by P. C. Bateman and J. G. Moore of new petrographic and chemical data from granitic rocks in the central Sierra Nevada with published results of laboratory experiments on igneous melts, indicates that the granitic rocks of the batholith differentiated and were emplaced at pressures of about 5,000 bars—pressures equivalent to a depth of burial of about 15 kilometers. This is in accord with data inferred from mineral assemblages in metamorphic rocks in the same area.

Local cataclastic structures found by Bateman, Moore, and Ronald Kistler in the granitic intrusives of the western Sierra Nevada, and in certain older plutons in the eastern Sierra Nevada, suggest that these intrusives have been involved in the later stages of regional deformation. The cataclastic structures dip steeply and are parallel to lineations in the metamorphic rocks, such as minor folds axes, elongate pebbles and minerals, and cleavage-bedding intersections.

Fritiof Fryxell has prepared a report on the geomorphology and glacial history of the upper San Joaquin River Basin from an incomplete manuscript, maps, field notes, diaries, and published reports of the late F. E. Matthes (1960). The report shows the distribution of Wisconsin and pre-Wisconsin glaciers and the location of the crests of moraines. The San Joaquin River flows through a narrow gorge of Pleistocene age, cut in the floor of a relatively mature Pliocene valley. The flanking uplands, which record a cycle of Miocene erosion, are surmounted in places by peaks that are clearly monadnocks.

Study by W. H. Jackson, F. R. Shawe, and L. C. Pakiser, Jr., (Art. 107) of gravity data in Sierra Valley, near the northern end of the Sierra Nevada, suggests that the valley is bounded on the north and west by steeply-dipping faults and is filled with Cenozoic deposits at least 2,500 to 3,000 feet thick.

Hydrologic studies

In a preliminary analysis of recent climate trends W. D. Simons (Art. 8) points out that during the last 15 years the downward trend formerly exhibited by most streamflow records in the Columbia River Basin has been reversed. During the same period, annual precipitation has increased, and annual mean temperature has decreased.

Measurements of stream velocity and related size of transported particles made by R. K. Fahnestock (Art. 87) in the White River below Emmons glacier, Mount Rainier, Wash., showed that boulders as much as 1.8

feet in intermediate diameter were being moved by water with a velocity of about 7 feet per second. This is a lower velocity than the "sixty power law" would require.

In studies of the chemical character of precipitation at Menlo Park, Calif., H. C. Whitehead and J. H. Feth (Art. 304) have determined that the winter rains contain appreciable amounts of sodium chloride derived from the ocean, whereas the soluble parts of dust and occluded gases that fill the air and accumulate on the ground between rains contain appreciable amounts of calcium sulfate. Thus the streams receive slightly more sodium chloride during the rainy winter months and slightly more calcium sulfate during the dry summer months.

According to J. H. Feth (Art. 84), streams originating along the California coast contain almost twice as much dissolved salt in summer as they do in winter as a consequence of the small amount of summer rainfall. Streams originating along the southern coast contain appreciable amounts of sulfate, chloride, calcium, and magnesium derived from the loosely consolidated sedimentary rocks. Streams in northern California are relatively low in these substances because the igneous and metamorphic rocks that border the coast are relatively insoluble.

On the Alameda Plain at the southeast end of San Francisco Bay, salt water from the bay is contaminating a deeper fresh water aquifer through abandoned wells. R. P. Moston and A. I. Johnson (Art. 386) have located points of leakage in the wells by use of geophysical methods. Gamma radiation, temperature, fluid-resistance, and self-potential logging methods were used. The logs were made under pumping, recharge, and static conditions.

Hydrologic studies in the San Joaquin and Sacramento Valley are summarized on pages A-71 and A-90.

ALASKA

During the past year, geologic mapping, geophysical and geochemical surveys, and surface- and groundwater studies were carried out in all the major regional subdivisions of the State. (See fig. 2.) This work has resulted in a number of new scientific and economic findings of regional significance, which are summarized below. Results of work on permafrost are summarized on pages A-61 and A-65 to A-66, and work on highway geology is summarized on page A-88.

Northern Alaska

Geologic mapping of the Project Chariot test site area on the northwest coast of Alaska by R. H. Campbell (Art. 354) demonstrates that the structure of the southern Lisburne Hills is dominated by gently folded imbricate thrust plates. The thrust plates, which are composed of the Lisburne group of Mississippian age, have moved eastward over Lisburne and younger strata. The thrusting is interpreted as a near-surface phenomenon caused by gravity gliding down the regional dip.

G. W. Moore (Art. 220) has concluded from a study of Ogotoruk beach sediments in the Project Chariot test site area that the principal sorting occurs during the transition from calm to storm profiles, when a large percentage of the beach sediment is processed, rather than during periods when the beach profile is in equilibrium.

Work in progress on the distribution of post-glacial beach deposits at Cape Krusenstern indicates that the deposits preserve a faithful record of the average angle of wave attack and hence of past wind direction. A cyclic alternation with a period of approximately 1,000 years has occurred between predominant southeast winds of the past and predominant northwest winds of the present.

A gravity profile by D. F. Barnes and R. V. Allen along the coastline between Point Hope and Kotzebue shows a 30-milligal low in the Cape Seppings-Kivalina area. This low is apparently produced by the thick prism of Mesozoic sediments that lies between the Tigara uplift and the Brooks Range geanticline. Although no profiles were made normal to the coastline, inland and coastline profiles overlap in places and clearly show a positive gradient of about 1 milligal per mile toward the Chukchi Sea.

The so-called "Okpilak" granite in the Mt. Michelson area of the eastern Brooks Range has been assigned a Paleozoic (Devonian?) age by E. G. Sable on the basis of lead-alpha age determinations of zircon fractions. The emplacement of the granite may have been contemporaneous with the development of an east and northeast-trending Paleozoic orogenic belt, oblique to the later "Laramide" belt of northern Alaska and northwestern Canada.

In a taxonomic study of brachiopod collections from the so-called "Arctic Permian" of the DeLong Mountains, J. T. Dutro, Jr., (Art. 231) has described a distinctive assemblage including *Licharewia*, *Horridonia*, *Waagenoconcha*, *Stepanoviella*, and others. The "Arctic Permian" is an equivalent of the Kazanian (Upper Permian) of Russia. Correlation with the Capitan of West Texas is also suggested.

West-central Alaska

Geologic mapping in the Koyukuk basin area by W. W. Patton, Jr., and A. R. Tagg has provided evidence of a major northeast-trending fault. The fault,

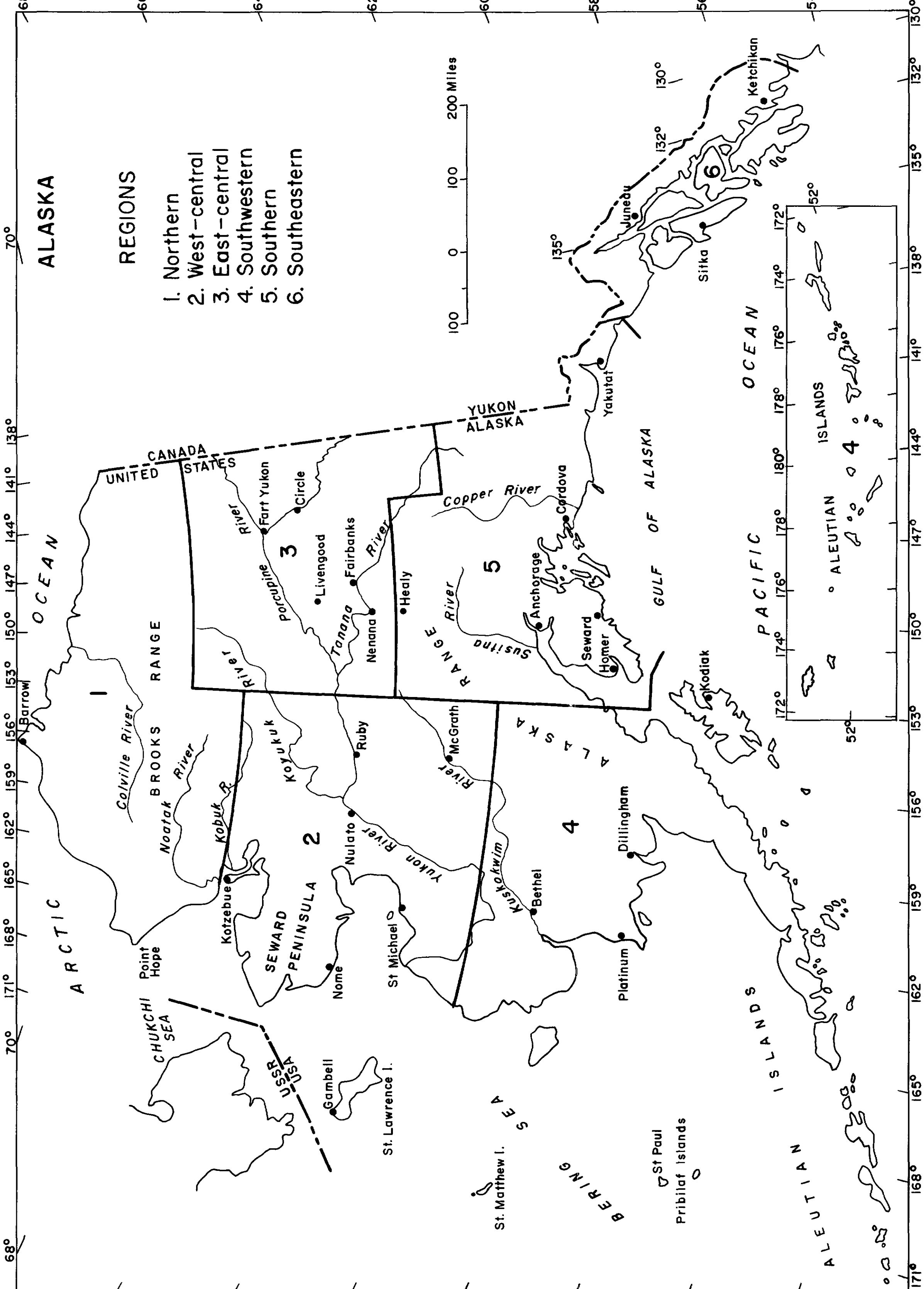

FIGURE 2.—Index map of Alaska showing boundaries of regions referred to on accompanying pages.

which extends from Unalakleet at least to Tanana, a distance of about 275 miles, is an outstanding tectonic feature as it offsets major structural features such as the Ruby geanticline and the Koyukuk geosyncline. The same project also furnished new evidence on the age of the thick sequence of folded volcanic rocks that surrounds the Koyukuk sedimentary basin. The volcanics, heretofore regarded as entirely Early Cretaceous (Neocomian) in age, are now known to range from Late Jurassic (Callovian) to late Early Cretaceous (Albian). The ammonite *Kepplerites* sp. of Late Jurassic (Callovian) age was found on the West Fork of the Buckland River in siltstone interbedded with the volcanics. Volcanic breccias on the Tagagawik River were traced laterally into graywackes of the basin sequence, which contain *Inoceramus altifluminus* McLearn of late Early Cretaceous (Albian) age.

New information on the age and character of rocks exposed along the lower Yukon River between Anvik and Mountain Village was obtained by J. M. Hoare. Rocks previously mapped as undifferentiated sediments of middle Cretaceous (Albian-Cenomanian) age were found to consist of a volcanic sequence ranging in age from Jurassic to Early Cretaceous, and a graywacke-mudstone sequence ranging in age from Jurassic to early Late Cretaceous.

On the Seward Peninsula, C. L. Sainsbury and others (Art. 151) have found that beryllium is concentrated in stream sediments around the principal tin-bearing granite stocks. Beryllium is particularly enriched in or near tin-bearing greisen and fluoritized tactite, and in local areas of argillic alteration of hypothermal origin, particularly in the Lost River area.

In the Kigluaik Mountains near Nome on the Seward Peninsula, regionally metamorphosed contact zones containing deposits of scheelite and sulphide minerals were recognized by C. L. Hummel (Art. 356). The mineralization probably explains the geochemical anomalies in stream sediment samples reported previously by Hummel and Chapman.[11]

East-central Alaska

Regional mapping in the Chandalar, Arctic, and Christian quadrangles by W. P. Brosgé and H. N. Reiser has provided new stratigraphic and paleontologic data on older Paleozoic rocks of the south flank of the Brooks Range. The pre-Mississippian stratigraphic sequence from oldest to youngest is: Skajit limestone Middle (?) Devonian, formerly believed to be Silurian); a unit of pink-weathering limestone, siltstone, and sandstone, heretofore unrecognized (Middle (?) Devonian, and lower Upper Devonian); a slate-sandstone unit (Upper Devonian); Kanayut conglomerate (Upper Devonian). Sheared conglomerate at the base of the slate-sandstone unit intertongues with the underlying pink-weathering rocks, and both units rest disconformably on the Skajit limestone. The slate-sandstone unit includes graywacke, chert, and volcanic rocks in the eastern part of the area. Among the fossils found is the rare Upper Devonian fossil plant *Pseudobornia ursina* Nathorst, identified by S. H. Mamay.

Surveys by D. F. Barnes (Art. 383) have established the presence of a gravity low of about 40 milligals in the Minto Flats area of the Tanana River valley. The low suggests that the alluvium-covered Minto Flats may be underlain by a structural basin containing as much as several kilometers of unconsolidated and semiconsolidated Cenozoic sediments. The low has a steep gradient along the eastern margin of the flats, which indicates that the Cenozoic sediments are probably downfaulted against the Precambrian schists of the adjoining uplands. Physiographic observations by D. M. Hopkins suggest that the Minto Flats are actively subsiding and are accumulating sediments at the present time.

Southwestern Alaska

In the Iniskin-Tuxedni area, R. L. Detterman has completed a study of one of the thickest sections of Jurassic rocks on the North American continent. Four Jurassic formations are recognized: Talkeetna (Lower Jurassic) 8,000 to 9,000 feet thick; Tuxedni (Middle Jurassic) 9,000 feet; Chinitna (Upper Jurassic) 2,400 feet; and Naknek (Upper Jurassic) 4,700 feet. An ammonite faunule from the lower part of the Bowser member of the Tuxedni formation has been dated as late Bajocian age by R. W. Imlay. It is of special interest because it includes genera unknown elsewhere and because it is the only evidence of rocks of late Bajocian age in North America north of southern Mexico.

New collections of Tertiary fossils from the Alaskan Peninsula, examined by F. S. MacNeil, indicate that some of the older collections of fossils must have been made from stratigraphic sequences in which there are significant time breaks. No marine Eocene is now recognized on the peninsula, and beds formerly assigned to the Eocene are now considered Oligocene. These new findings necessitate complete revision of published Tertiary sections.

Southern Alaska

In the southwestern part of the Talkeetna Mountains, fossil plants recently collected by A. Grantz, D. L. Jones, and F. F. Barnes, and identified by J. A. Wolfe, suggest

[11] Hummel, C. L., and Chapman, R. M., 1960, Geologic and economic significance of some geochemical results obtained from stream sediment samples near Nome, Alaska, *in* Short papers in the geological sciences: U.S. Geol. Survey Prof. Paper 400–B, p. B30–B33.

that the dominantly nonmarine Arkose Ridge formation is of Albian and possibly Cenomanian age. Most earlier workers had considered the Arkose Ridge formation to be Eocene on the basis of a few fossil plants. The new findings suggest that the Arkose Ridge formation is correlative with nearby marine beds at the base or in the lower part of the Matanuska formation, which ranges from Albian to Maestrichtian in age.

Geologic maps of the Gulf of Alaska Tertiary area, a possible petroleum province, have been compiled at a scale of 1:96,000 by D. J. Miller (1961a–e). Marine sedimentary rocks of late Tertiary age occur in a small area just north of Cape Fairweather. To the northwest, as far as Yakutat Bay, the exposed rocks of the coastal lowland and bordering uplands are interbedded volcanic and sedimentary rocks of probable early or middle Mesozoic age, overlain unconformably by argillite and graywacke of the late Mesozoic Yakutat group. The argillite and graywacke of the Yakutat group grade southeastward into bedded schist at the Alsek River. Pelecypods of the Late Jurassic-Early Cretaceous genus *Buchia*, collected from the basal part of the Yakutat group, are the first diagnostic fossils reported from these beds in the type area.

Southeastern Alaska

In mapping the coastline of northern Baranof and adjacent smaller islands, H. C. Berg and D. W. Hinckley have established 3 formations of presumed Paleozoic age, 2 of Mesozoic age, and 1 of Quaternary age, based on gross lithologic and metamorphic characteristics. Rocks underlying several hundred square miles in the northeastern part of the island, formerly considered to be Paleozoic, were reassigned to the Triassic(?). The pre-Quaternary rocks of northern Baranof Island are complexly folded, cut by many faults, and metamorphosed by intrusion of the Coast Range batholith complex. Evidence for at least two stages of deformation was recognized. The southwest half of Baranof Island is underlain by a broad anticlinorium, and the northeast half by a broad synclinorium. Both structures trend northwestward.

A reexamination of old fossil collections by J. T. Dutro, Jr., and R. C. Douglass (Art. 101) has demonstrated the presence of Middle Pennsylvanian rocks in southeastern Alaska. Fossils from Saginaw Bay, northern Kuiu Island, include two species of *Fusulinella* together with species of *Rhipidomella*, *Chonetina*, *Linoproductus*, *Spirifer*, *Rhynochopora*, and *Straparollus* that indicate an early Middle Pennsylvanian (Atoka) age.

Cenozoic stratigraphy of Alaska

Recent paleontologic and stratigraphic investigations have led to changes in the age assignments of Cenozoic rocks in many parts of Alaska, to advances in the understanding of the climatic history of Alaska, and to better knowledge of the evolution of the floras of Alaska. Some stratigraphic units that have long been regarded as Eocene in age have yielded leaf floras or molluscan faunas indicative of an Oligocene age. Continental sediments of late Tertiary age were discovered to be much more widely distributed than previously known. D. M. Hopkins, Stearns MacNeil, and E. B. Leopold (1960) have established that the coastal plain at Nome is underlain by an almost unbroken sequence of marine, glacial, and colluvial deposits ranging in age from late Pliocene to Recent, which they propose as a type section for the late Cenozoic stratigraphy of the Bering Strait area. The improved knowledge of Tertiary stratigraphy has established that tectonic activity continued throughout Tertiary time in Alaska. The present topography and drainage in many parts of Alaska are products of crustal deformation during late Tertiary time.

According to T. L. Péwé (Art. 357) four Quaternary glaciations, as well as minor historic advances, are recorded on the south side of the central Alaska Range in the region of the headwaters of the Delta River.

Aeromagnetic profiles

Total intensity aeromagnetic profiles have been compiled by G. E. Andreasen (1960b) for parts of the Kobuk, Minchumina, Cape Espenberg, Cape Lisburne, and Brooks Range areas. In the Cape Espenberg area the profiles indicate several east-trending magnetic highs beneath the cover of Cenozoic volcanic rocks. These highs probably represent the feeding fissures. On the Cape Lisburne Peninsula the profiles were used to trace a belt of mafic igneous rock through unmapped and covered areas. Along the Kobuk River valley the profiles clearly show the contact of Cretaceous sediments and Mesozoic volcanic rocks beneath the cover of alluvium.

Quartz diorite line

The quartz diorite boundary line, which was defined in western conterminous United States by J. G. Moore [12] has been traced northward through Alaska to the Bering Sea by J. G. Moore, A. Grantz, and M. C. Blake, Jr., (Art. 183). This line separates a coastal zone, in

[12] Moore, J. G., 1959, The quartz diorite boundary in the western United States; Jour. Geology, v. 67, no. 2, p. 198–210.

which quartz diorite is the dominant rock, from an inland zone, in which granodiorite, quartz monzonite, or granite is the dominant rock. From the latitude of Ketchikan to that of Skagway, the line is near the boundary between Alaska and Canada. From Skagway it trends northwestward on the north side of the St. Elias and Wrangell Mountains to a point about 70 miles south of Fairbanks; it then curves to the southwest and finally passes out to sea at Bristol Bay. The arcuate path of the line across southern Alaska generally parallels the trend of the Mesozoic and Cenozoic tectonic elements.

Surface water

The volume of water released from storage in Lake George, the famous ice-dammed lake near Palmer, Alaska, was about 1.1 million acre-feet in July 1960, according to R. E. Marsh. This was about 30 percent greater than the 1959 release but only about 70 percent of the average for the 13-year period 1948–60. The release of stored water occurs each year when the ice dam washes out. The peak flow in 1960 was 328,000 cubic feet per second, the third highest during the 13-year period of record and about 1.3 times the average for the period.

Measured runoff in Alaska streams during the water-year ending September 30, 1959, ranged from 9 to 294 inches (U.S. Geological Survey, 1961g), a little lower than the average for the last 10 years.

Ground water

As part of a study of ground water in the Matanuska Valley, F. W. Trainer (1960) has shown that moderate supplies of good quality water for domestic, irrigation, and municipal use are available from glacial and glaciofluvial aquifers.

In the Fairbanks agricultural area many homes have been built without adequate water supplies because of high drilling costs and because of lack of knowledge of ground-water occurrence under permafrost conditions. A solution to this problem has been found by D. J. Cederstrom and G. C. Tibbitts, Jr., (1961) who have recently described an economical and effective method of jetting to aquifers beneath frozen silt.

Permafrost and ground-water relations at Fairbanks and elsewhere in Alaska are summarized in the section on permafrost.

HAWAII

Geologic and hydrologic investigations in Hawaii include observations on volcanoes, studies of alumina-rich soil and weathered rock, studies of the geology and water resources of specific areas, and the collection of basic data on surface and ground water. The water resources studies and the studies of alumina-rich soil are carried on in cooperation with the Division of Water and Land Development of the Hawaii Department of Land and Natural Resources.

Kaupulehu lava flow, Hualalai Volcano

A better understanding of the genesis of alkalic basalt flows that mantle Hualalai Volcano has been obtained through studies by D. H. Richter and K. J. Murata (Art. 89) of xenolithic nodules in the Kaupulehu flow of 1801. The nodules, which occur in abundance in the flow, are subrounded crystal aggregates of clinopyroxene, olivine, and feldspar. The mineralogy of the nodules and their abundance support the view that the alkalic basalt magmas were derived from tholeiitic magmas primarily by fractional crystallization of pyroxene.

New data on the 1959–60 eruption of Kilauea Volcano

Data obtained during and after the 1959–60 eruption of Kilauea are yielding new insights into the physics and chemistry of Hawaiian volcanism. Analysis of tiltmeter and leveling data by J. P. Eaton and H. L. Krivoy indicates that the summit region of Kilauea began to detumesce rapidly soon after the start of the 1960 flank eruption at Kapoho, and then reached a state of rest that lasted from July to October, 1960. At the end of the period of detumescence a resurvey was made of part of a level-line network established by the Topographic Division in 1958. The resurvey showed that an area of 24 square miles in the summit region had subsided a foot or more, with a maximum subsidence of more than 5 feet on the floor of the caldera. The volume of detumescence was roughly equivalent to the volume of lava extruded (210,000,000 cubic yards) during the 1959-60 activity. The pattern and amount of detumescence as revealed by levelling were about the same as predicted by analysis of data from the liquid-level tiltmeters.

The deep pond of lava that accumulated in Kilauea Iki crater during the 1959 eruption has been the subject of a continuing study by W. U. Ault, J. P. Eaton, and D. H. Richter. A hole was drilled 12 feet into the crust of the pond in August 1960, and subsequently deepened to 22.8 feet, where molten lava with a temperature of 1065° C was encountered. By October 4, 1960, the bottom temperature had dropped to 1041° C and the bottom was solid. On December 20, 1960, the bottom temperature was down to 1000° C. The 600° C isotherm declined from 6¼ to 10¼ feet below the surface during the seven-month period of measurement. For two weeks following the drilling in August, highly fluid magma oozed into the bottom 5 inches of the hole. This material contained 54 percent silica and represents an extreme tholeiitic differentiate of the pond lava, which originally contained about 48 percent silica.

Studies by K. J. Murata and D. H. Richter of the chemistry and mineralogy of the lavas extruded during the 1959–60 eruption of Kilauea indicate that the summit lavas of 1959 are primitive materials that rose rapidly from great depth, whereas the flank lavas of 1960 are differentiated derivatives of primitive lava. The summit lavas are olivine basalt and were erupted at relatively high temperature. In contrast, the flank lavas are high in silica, contain abundant pyroxene and plagioclase phenocrysts, and were erupted at a lower temperature.

Uwekahuna laccolith in Kilauea caldera

Petrographic and chemical studies by Murata and Richter of rocks from the Uwekahuna laccolith exposed in the wall of Kilauea caldera revealed that relatively thin basaltic intrusive bodies may undergo extreme differentiation. Gravitational settling of olivine through the central portion of the laccolith has formed a picrite (46 percent SiO_2), and filter pressing of residual liquids has developed dikelets of aphanitic rock approaching quartz basalt in composition (52 percent SiO_2). This range in composition is about as great as that found among all hitherto analyzed lavas from Kilauea Volcano.

Alumina-rich soil and weathered rock

Investigation by S. H. Patterson and C. E. Roberson (Art. 219) of alumina-rich soils and weathered rocks in deeply weathered basalt lava flows of Kauai and Maui shows that thoroughly weathered rock at the surface is rich in gibbsite (aluminum hydroxide) and secondary iron minerals, and that with depth the amount of gibbsite decreases and clay minerals of the kaolin group become the major component. Leaching by acid ground water is the principal cause of weathering. Water in the weathered basalt has a pH of 4.6 to 5.9, and water in unweathered basalt has a pH slightly above 7. Part of the gibbsite occurs as virtually pure irregular nodules, but most of it is intimately associated with secondary iron minerals in pseudomorphs of original minerals in the basalt, in nodules, concretions, and vein fillings, and as clay-size particles. Sampling and analytical work by Patterson show that large tonnages of gibbsite are present in the eastern part of Kauai and in the northern part of east and west Maui, but the deposits are of low grade and are not of economic interest at present.

Geology of Kauai

Studies of the island of Kauai by G. A. Macdonald, D. A. Davis, and D. C. Cox (1960) show that it is structurally the most complex of the Hawaiian Islands. Kauai is a large shield volcano that has been profoundly altered in form by collapse, erosion, and late volcanic activity. The major shield is composed predominantly of olivine basalt flows, but includes a small amount of basaltic andesine andesite that was extruded late in the period of eruptive activity. In the deeply eroded eastern part of the shield large areas are covered by lava, cinders, and ash that were extruded from many subordinate vents very late in the period of eruptive activity. These late lavas include olivine basalt, picrite basalt (mimosite), basanite, nepheline basalt, melelite-nepheline basalt, and ankaratrite.

Ground water in southern Oahu

Studies by F. N. Visher and J. F. Mink (1960) in southern Oahu show that the large, fresh ground-water system in the Honolulu and Pearl Harbor area is virtually in equilibrium with sea water under prevailing conditions of recharge, pumping, and use of water on irrigated sugarcane fields. During periods of minimum flow and maximum demand about 50 mgd (million gallons per day) of water of good chemical quality discharges into Pearl Harbor from springs and nearshore wells. The water flowing into the sea could be salvaged if it were collected below the points of discharge and pumped to areas of need. Some might be salvaged also by pumping from inland wells, although this action would upset the equilibrium and cause an increase in salinity of water in some areas.

In geochemical studies of the ground water of southern Oahu, J. F. Mink (1960b) has found that the concentrations of calcium and magnesium in the intruded sea water underlying the fresh-water lens are greater than in the open ocean, and that the concentrations of sodium and potassium are less. The differences are attributed to cation exchange that takes place as sea water moves through calcareous and alluvial deposits on the ocean bottom before entering the basaltic aquifer.

Fluctuations in thickness of the fresh water lens underlying southern Oahu are being determined by F. N. Visher (1960) from study of fluctuation of the level of salt water in a deep observation well drilled below the bottom of the lens.

An analysis of E. R. Lubke (Art. 359) of records of wells tapping ground water in lava flows in southern Oahu shows a generally nonlinear relationship between discharge rate and drawdown. From this relationship drawdown in most wells can be estimated for most discharge rates.

Use of water by phreatophytes on Oahu

In the Waianae district of Oahu, C. P. Zones (Art. 377) has found that water transpired by algaroba, a variety of mesquite, probably is a large component of the total ground-water discharge in the semiarid coastal area of western Oahu. A daily rise and fall of the water table is attributed to the use of water by algaroba, which grows in dense stands over a considerable part of the area.

Water resources of windward Oahu

Hydrologic studies of northeast, or windward, Oahu, by K. J. Takasaki, G. T. Hirashima, George Yamanaga, and E. R. Lubke, show that large quantities of ground water are in storage in the volcanic rock at altitudes below 600 feet. The water is in many compartments or reservoirs, most of them small, bounded laterally by dikes cutting the lava flows and capped by relatively impermeable deposits of alluvium. Ground water discharging from these small reservoirs contributes to the base flow of streams emptying into the sea along the windward shore of Oahu.

INDIAN RESERVATIONS, NATIONAL PARKS, AND PUBLIC LANDS

Saratoga National Historical Park, New York

A study by R. C. Heath and J. A. Tannenbaum showed that a water supply sufficient for the needs of the Saratoga National Historical Park may be obtained from a small isolated body of sand of Pleistocene age that underlies the northeastern corner of the park. Springs issuing from the same body of sand supplied the British army during the Battle of Saratoga.

Hydrology of the Everglades National Park, Florida

Geologic studies by Howard Klein show that the eastern part of Everglades National Park is underlain by the Biscayne aquifer, chiefly of Pleistocene age. This aquifer is a shallow body of highly permeable limestone, calcareous sandstone, and sand, which yields fresh water in all but the coastal areas. Within the park the aquifer is replenished by local rainfall and by sheet flow and underflow from the north. Exploratory drilling in the central and southern parts of the park in 1960 indicated the widespread occurrence of dense limestone layers, 2 to 3 feet thick, at altitudes ranging from 5 to 15 feet below sea level. These layers are relatively impermeable and effectively retard the vertical movement of ground water, thus tending to form two separate flow systems within the Biscayne aquifer. The origin and perpetuation of the Everglades may be closely related to the near-surface occurrence of the limestone of low permeability that underlies all of the park south of the latitude of Miami.

Ground-water supply of Cape Hatteras National Seashore Recreational Area, North Carolina

Test drilling on Ocracoke Island indicates that only small supplies of fresh water are available. The island is separated from the North Carolina mainland by Pamlico Sound, which contains saline water. The island is underlain by unconsolidated sand and clay of Quaternary age to a depth of 90 or 100 feet below sea level. The water in this zone is fresh (P. M. Brown, 1960; Kimrey, 1960a). From 100 to at least 900 feet below sea level, the island is underlain by an artesian aquifer composed of consolidated shell limestone, unconsolidated sand, and clay of probable Miocene age, which contains saline water. Downward leakage of saline water from Pamlico Sound apparently has contaminated the aquifer.

Hydrologic studies in Indian Reservations, New Mexico

Latest Cretaceous and early Tertiary rocks along the east side of the San Juan Basin have been mapped by E. H. Baltz in conjunction with a hydrologic study of the southern part of the Jicarilla Apache Indian Reservation. Baltz subdivided the Eocene San Jose formation of Simpson,[13] which consists of as much as 1,800 feet of shale and sandstone, into four members on the basis of predominant lithology. The yields of stock and domestic wells in the San Jose suggest that a few hundred gallons per minute could be developed by penetrating the thick units of sandstone. Dry holes are common in the areas underlain by thick shale units.

On the Mescalero Apache Indian Reservation, studies by C. E. Sloan indicate that the Yeso formation of Permian age is a reliable source of unconfined ground water throughout much of the reservation. Locally, perched bodies of ground water in the overlying San Andres limestone of Permian age can supply water to relatively shallow wells.

Ground-water studies by G. A. Dinwiddie in the Acoma and Laguna Indian Reservations indicate that the principal aquifers are alluvium and basalt of Quaternary age in the valley of Rio San Jose and its tributaries. Yields of 15 to possibly 500 gallons per minute can be obtained from these aquifers.

Water-supply possibilities at Capitol Reef National Monument

An evaluation of water-supply possibilities at Capitol Reef National Monument, Utah, indicates that ground water probably can be obtained from wells penetrating the Coconino sandstone of Permian age. The top of the Coconino sandstone should be encountered at a depth of about 1,350 feet and wells should yield about 50 gallons per minute of potable water.

Hydrology of Fort Apache Reservation, Arizona

In a study of the hydrologic effect of eradication of juniper and piñon pine on Fort Apache Reservation,

[13] Simpson, G. G., 1948, The Eocene of the San Juan Basin, New Mexico, pt. 1: Am. Jour. Science, v. 246, no. 5, p. 257–282; pt. 2, no. 6, p. 363–365.

Ariz., R. C. Culler reports that no significant percolation of water was observed below a depth of 7 feet in a silt-loam soil during a period of 18 months. For 12 months of the period, precipitation was 150 percent of normal.

PUERTO RICO

The U.S. Geological Survey is making detailed studies of the geology and mineral resources of Puerto Rico in cooperation with the Department of Industrial Research of the Economic Development Administration, and studies of the surface and underground waters and the quality of water in cooperation with the Puerto Rico Water Resources Authority, the Puerto Rico Aqueduct and Sewer Authority, the Puerto Rico Industrial Development Company, and the Legislative Assembly of Puerto Rico. Some of these studies are summarized below. Others are summarized in other sections of this report as follows: sources of domestic water, page A–8; lateritic saplolite, page A–61; landslides, page A–89; and shoreline erosion, page A–90.

Structural control of mineralization

Detailed geologic mapping, now covering about one-third of the mainland of Puerto Rico, has shown that the general structural trends in the mountainous core of Puerto Rico are west to west-northwest (Pease and Briggs, 1960). Zones of hydrothermally altered rocks generally follow shear zones that are parallel to these trends (Pease and Briggs, 1960; Berryhill and Glover, 1960) and exposures of plutonic dioritic and quartz dioritic rocks also trend generally in the same directions. Mineralization appears to be most prominent where the hydrothermally altered rocks are closely associated with the plutonic rocks (Hildebrand, Art. 91).

Stratigraphic studies in east-central Puerto Rico are beginning to show that the predominantly marine sediments and pillow lavas of the Robles formation grade laterally into an as yet unnamed sequence of subaerial to shallow marine volcanic breccia and lava.

Test well for petroleum drilled on north coast

According to R. P. Briggs, the first deep test well drilled in the northern part of Puerto Rico—Kewanee Interamerican Oil Company's Commonwealth of Puerto Rico No. 4—penetrated the entire sequence of Oligocene and Miocene rocks; this sequence comprised the upper 5,550 feet of the 6,434-foot test well. As revealed in the well, the Cibao formation is composed of limestone and clastic, shaly sediments, whereas in outcrop only 12 kilometers up dip to the south the Cibao is nearly solid limestone, although clastic rocks are present both southeast and northwest of the well. A large fault probably lies south of the test well, near a line of springs, as the Tertiary formations were penetrated at depths greater than indicated by regional dips. The contrast in lithology of the Cibao formation penetrated in the well compared to the outcrop suggests a large strike-slip fault.

Ground water

The flow from the hot spring at Baños de Coamo was estimated at 30 gallons per minute at the end of the dry season in February, 1960, and at 220 gallons per minute after a period of heavy rainfall in September, 1960. Although the flow varied markedly, the temperature of the water was 110° F at both times, and chemical analyses show no appreciable change in the type or quantity of dissolved constituents. The data indicate that the spring water is derived directly from rainwater which percolates deep into the earth and then rises rapidly along a fault plane; changes in rate of flow reflect pressure changes in the hydrostatic head (Arnow and Crooks, 1960).

The water table in the karst area of northern Puerto Rico seems to have a very flat gradient not far above sea level for several kilometers inland from the coast; this indicates extremely high permeability in a limestone honey-combed by solution channels (Arnow, Art. 221).

Floods of September 6, 1960

Disastrous maximum floods occurred September 6, 1960, in the eastern half of Puerto Rico as hurricane Donna passed by to the north. A special flood team assembled by the Geological Survey reached the area within a few days and made surveys and computations of peak discharge at 23 sites on selected rivers. This was the first study of a major flood ever made in Puerto Rico. The peak discharge per square mile of drainage area at four of the sites exceeded commonly accepted world maxima, and few rates of comparable magnitudes are known. For instance, the peak discharge of Rio Valenciano near Las Piedras was 28,800 cubic feet per second from a drainage area of 6.86 square miles (Barnes and Bogart, 1961).

CANAL ZONE

A study of Tertiary mollusks of the Canal Zone by W. P. Woodring has yielded data on the importance of the Panama land bridge as a sea barrier. Many genera of mollusks formerly living in the eastern Pacific Ocean and the Caribbean Sea became extinct in the Caribbean Sea during Pliocene time, but still survive in the eastern Pacific. This relation suggests that the local extinction is the result of changes in oceanic circulation when the Panama land bridge came into existence, during Pliocene time.

WESTERN PACIFIC ISLANDS

Geologic investigations of the scattered western Pacific Islands (fig. 3) continue to provide information that will further the economic development of a large area now under jurisdiction of the United States, and will advance knowledge of geologic principles and the geologic history of the Pacific Ocean area. Most of the investigations have been undertaken with the cooperation and support of other Federal Agencies, especially the U.S. Army Corps of Engineers.

Geology of Ishigaki, Miyako, Tinian, and the Yap Islands

Studies of Ishigaki and Miyako in the Ryukyu Islands, Tinian in the southern Mariana Islands, and the Yap Islands in the western Caroline Islands emphasize the diversity of the physiography, vegetation, geology and soils of islands bordering the Philippine Sea.

Ishigaki Island has a complex terrain (Helen Foster and others). Densely forested mountains, rising to altitudes of 500 meters and more, are bounded by cultivated and grass-covered hills and dissected marine terraces. Low, nearly level alluvial areas at the mouths of the larger streams are sites of rice cultivation, swamps, and local peat accumulation. The mountains and hills consist of folded, faulted, and metamorphosed Paleozoic(?) rocks, Mesozoic or early Tertiary granite and granodiorite, and Eocence volcanic rocks and limestone. Similar rocks lie beneath late Tertiary and Quaternary gravel and reef limestone that form the marine terraces.

In contrast, islands of the adjacent Miyako group are relatively simple. Low long parallel ridges, intervening tilted plateaus, and coastal terraces of Pliocene, Pleistocene, and Recent limestones and associated sediments overlie a thick sequence of late Tertiary shales, marls and sands. The late Tertiary sequence is well exposed only along the steep, faulted east coast of the island. The variety of soils is limited and well-developed forests are lacking (D. B. Doan and others).

Tinian also has a low and simple terrain characterized by a broad faulted limestone plateau, coastal terraces, and little variety of soils and vegetation (Doan, Burke, May, and Stensland, 1960). On this island limestone overlies volcanic deposits of probable early Tertiary age. Outcrop areas of the volcanic deposits are small and inconspicuous when compared to those of Saipan to the north and Guam to the south.

The Yap Islands are characterized by rolling forested and grass-covered hills. They are underlain by pre-Tertiary metamorphosed volcanic rocks, by small bodies of ultrabasic intrusive rocks, mostly serpentinized, and by Tertiary breccias that are partly tectonic and partly sedimentary in origin. Areas of badlands topography are barren or grass- and fern-covered and are underlain by deeply weathered Miocene volcanic rocks according to C. G. Johnson and others. Soils of the metamorphosed volcanic rocks are predominantly shallow silty clay lithosols; those of the ultrabasic rocks are deeply colored granular latosols; and those of the volcanic rocks are humic latosols, a common soil type on volcanic rocks of the western Pacific Ocean. Exposures of pre-Tertiary metmorphic rocks, ultrabasic intrusive rocks, and their characteristic soils are unknown elsewhere along the east margin of the Philippine Sea.

Paleontologic studies of Okinawa, Guam, and the Fiji Islands

L. W. Leroy has found that fossil Foraminifera from deep drill holes and surface exposures in Tertiary and Quaternary sediments of Okinawa, Ryukyu Islands, correlate with other faunas of the Far East that range in age from late Oligocene to Pleistocene. The faunal succession indicates that the enclosing sediments were deposited at shallow bathyal and deep neritic depths from late Oligocene to late Miocene and at shallow depths during the late Pliocene and Pleistocene. The late Miocene and early Pliocene foraminiferal assemblages of the drill holes represent alternating shallow and deep water environments of deposition, which may have resulted from tectonic movements or submarine slides and turbidity currents accompanying uplift of the southern half of the island.

Recognition by Ruth Todd of a *Globigerina ampliapertura* zone in deposits on Guam, Mariana Islands, which have been dated as lower Oligocene on the basis of other Foraminifera, strengthens the evidence for an Oligocene age for this zone in other parts of the world.

Faunal studies of larger Foraminifera in four samples from Viti Levu, Fiji Islands not only establish the presence of Tertiary *b* (upper Eocene) sediments and Tertiary *c* (Oligocene) limestones on this island, but also provide important connecting links in the geographic distribution of the early Tertiary foraminiferal faunas of the Indo-Pacific area (Cole, 1960). The Tertiary *b* fauna is identical with faunas described from Saipan and other islands of the western Pacific Ocean.

Volcanic suites of Guam and Pagan, Mariana Islands

Field studies of J. I. Tracey, Jr., S. O. Schlanger, J. T. Stark and others show that late Eocene and early Oligocene volcanic rocks of central Guam were derived from a former volcano to the west of the island. Early Miocene volcanic rocks of southern Guam came from a second now-collapsed volcano southwest of the island. Results of chemical and trace-element analyses of the

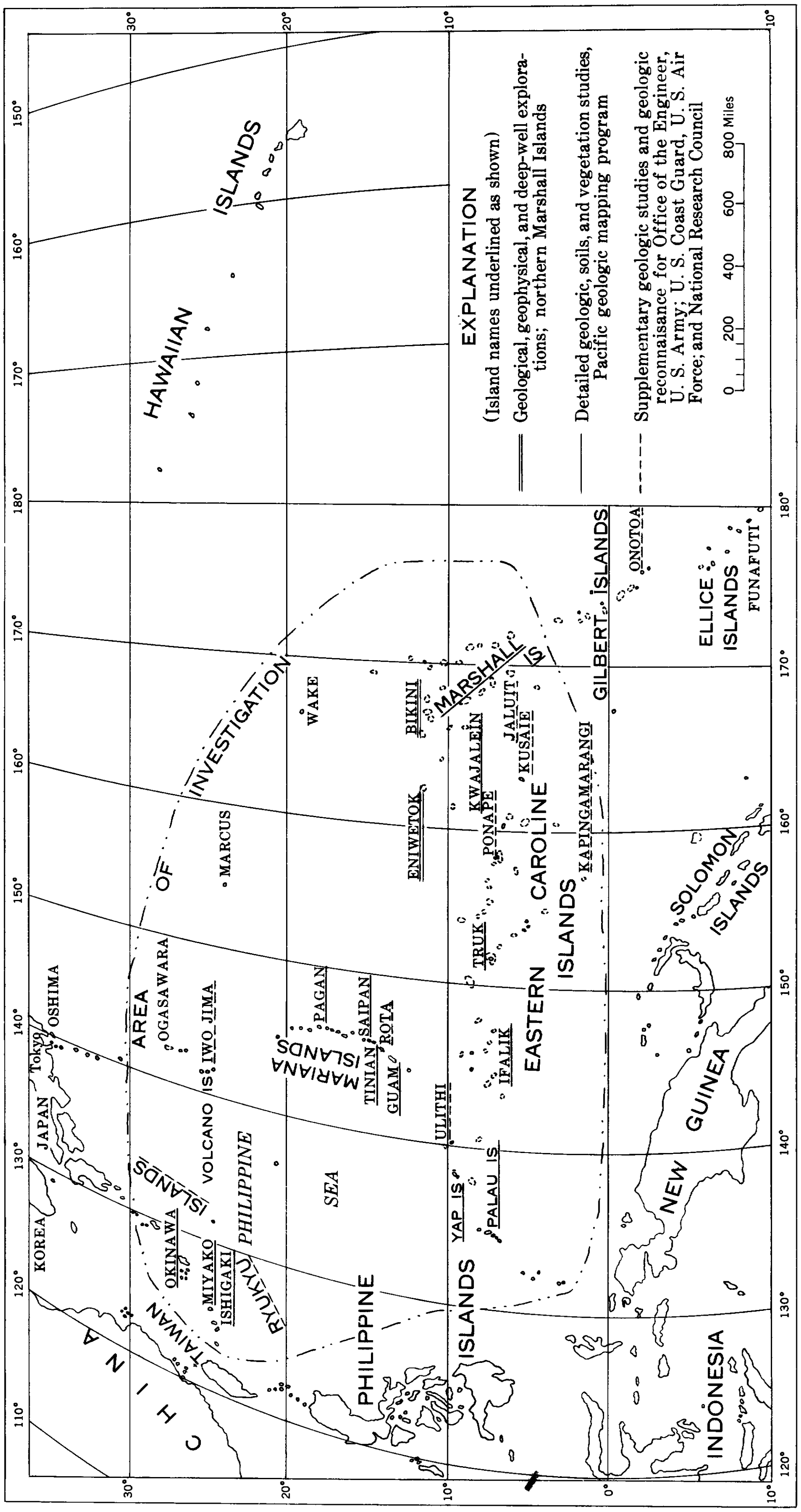

FIGURE 3.—Index map of western Pacific Islands showing areas investigated by the U.S. Geological Survey.

two volcanic sequences suggest two independent differentiation series.

Suites of Quaternary volcanic rocks from Pagan and other northern Mariana Islands differ significantly from described suites of most other islands situated on the east margin of the Philippine Sea (Corwin, Art. 223). Petrographically and chemically, the northern Mariana suites are intermediate between the alkalic suites, characteristic of volcanic rocks of Iwo Jima and Sin Iwo Jima in the Volcano Islands to the north, and the tholeiitic suites, characteristic of volcanic rocks of the southern Mariana, Yap, and Palau Islands to the south.

Studies of drill holes in the northern Marshall Islands

Detailed lithologic studies by S. O. Schlanger of samples obtained during drilling operations on Eniwetok Atoll from 1950 to 1952 (Ladd and Schlanger, 1960) show that below both Eniwetok and Bikini Atolls, rocks characterized by fossil molds and solution channels alternate vertically with rocks containing primary skeletal aragonite. The leached zones, termed "solution unconformities," are directly overlain by unaltered unconsolidated sediments, and generally coincide with faunal breaks.

In deep drill-hole F-1 on Eniwetok Atoll, J. H. Swartz measured seismic in-hole velocities ranging from 6,500 to 17,000 feet per second, as determined by the projected-time method. A general increase, with many velocity variations, was recorded from the surface to a depth of about 2,100 feet, below which there was a general velocity decrease. The maximum velocity was measured at the level of a hard dense crystalline limestone showing few traces of organic structure.

Investigations of typhoon damage to atoll

Jaluit Atoll, southern Marshall Islands, has been restudied by D. I. Blumenstock, F. R. Fosberg, and C. G. Johnson (1961) to determine geomorphic and vegetation changes since initial surveys by McKee[14] and others (McKee, 1961a, b, c; Fosberg, 1961c, d, e), which were made shortly after passage of a typhoon in January, 1958. Most of the rubble ridge formed by the typhoon on the windward reef flats has migrated and become incorporated in the normal beach ridges; locally the ridge persists but has shifted shoreward. Extensive tracts of boulder-size coralline slabs that mark the former location of the ridge on the reef flats will probably become permanent features when stabilized and cemented. Gravel bars on the lagoon side of windward islets were little changed although locally enlarged by gravel deposited by normal storm waves within the lagoon. Ponds behind the gravel bars, gravel sheets on land areas, and scour pits and channels above the tidal zone also appear to be permanent features. Scour pits and channels that were cut across the islets within the tide zone are expected to fill slowly, and eventually the shorelines should approximate their former positions. The Ghyben-Herzberg lens of fresh water had apparently returned to normal.

Johnson and Blumenstock also studied geomorphic changes on Ulithi Atoll, western Caroline Islands, caused by a typhoon that passed directly over the northern part of the atoll on a west-northwesterly course on November 30, 1960. General effects of this typhoon included temporary steepening of upper beach slopes and reduction of lower beach slopes by erosion, increase in height of islet margins by deposition of sediment washed upward from the beaches, temporary lengthening of spits at ends of the islets, and removal and construction of low bars. The generally high islets at Ulithi (altitudes commonly 10 to 20 feet, with a maximum of 23 feet) may directly reflect high typhoon frequency, in contrast to Jaluit Atoll, Marshall Islands, where typhoons are rare and the islets are generally 10 feet or less in altitude.

ANTARCTICA

Geologic studies in Antarctica, carried on in cooperation with the U.S. Antarctic Research Program of the National Science Foundation, were expanded in 1960 to include areal mapping at 1:250,000 scale in the eastern Horlick Mountains (fig. 4), the first geologic mapping undertaken by the United States in Antarctica. A Survey geologist accompanied the U.S. 1961 Bellingshausen-Ammundsen Seas Icebreaker Expedition to undertake reconnaissance geology along the Walgreen and Eights Coasts of Antarctica. Studies in coal geology, tectonics, petrology, and glaciology started in previous years were continued in 1960.

Geology of the eastern Horlick Mountains

The eastern part of the Horlick Mountains (fig. 4) is a flat-topped massif 30 miles long and 20 miles wide that rises as much as 3,000 feet above the surrounding ice plateau; the highest summits are about 9,100 feet above sea level. To the southeast of the main massif, nunataks are scattered along an escarpment in the ice plateau for an additional 40 miles. Bedrock is exposed mostly on the sides of the main massif and in the nunataks along the escarpment. A. B. Ford, B. G. Andersen, H. A. Hubbard, and J. M. Aaron, working during the 1960-61 austral summer, have found the northern part of the mountains to be underlain mostly by coarse-grained quartz monzonite or quartz diorite. Petrographic studies by Ford show hypersthene to be

[14] McKee, E. D., 1959, Storm sediments on a Pacific atoll: Jour. Sed. Petrology, v. 29, p. 354–364.

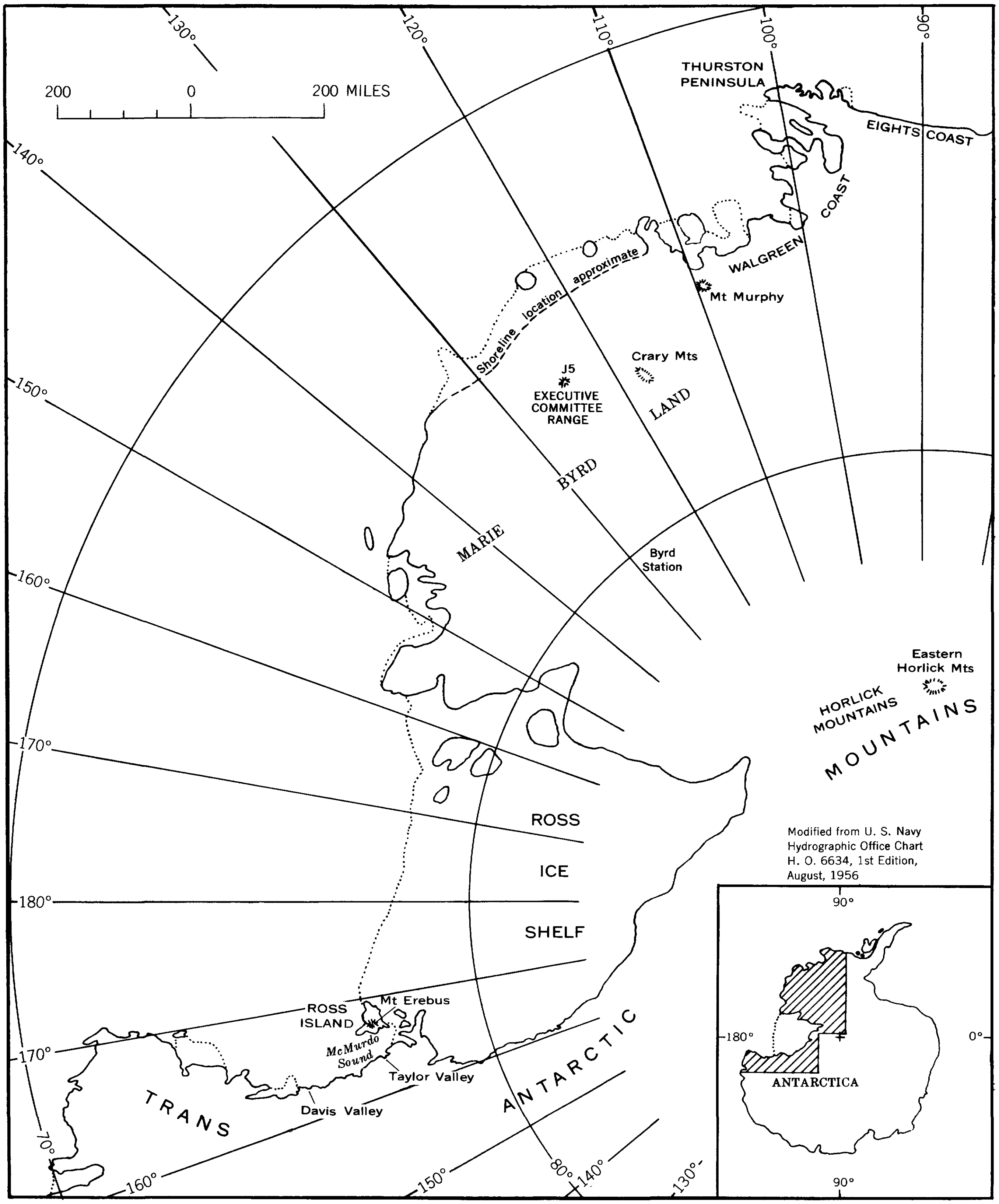

FIGURE 4.—Index map of part of Antarctica showing areas of geologic mapping, geologic studies, and geologic reconnaissance by the Geological Survey, 1957 through 1961.

a very common constituent, suggesting affinities with Precambrian(?) charnockitic rocks of East Antarctica. These rocks are assigned to the basement series of the trans-Antarctic mountains. The mesalike form of the main massif and the presence of a northeastward-trending ice escarpment suggest that normal faults are major structural elements of the mountains.

Geology of central Marie Byrd Land

Study of aerial photographs by E. L. Boudette and W. H. Chapman has shown that "Mount X Ray" (provisional) identified during "Operation High Jump," is in reality Mount Murphy (fig. 4), which previously was mislocated. The approximate true position of Mount Murphy is near the seacoast at lat 75°30′ S., long 109°30′ W. This is 40 to 50 miles southwest of the position shown on published maps. The new position of Mount Murphy requires a corresponding southwestward adjustment in the position of the coastline.

Boudette has recently described an unusual rhomb-porphyry, anorthoclase trachyte from the Crary Mountains, a group of stratovolcanoes (approximately lat 76°45′ S., long 117°30′ W.). The trachyte is similar to the "kenyte" of the Ross Island area and also to a rock from the Executive Committee Range. Thus, the Crary Mountains are part of a soda-alkaline volcanic province that extends from the western Ross Sea region through Marie Byrd Land. The presence of glass in the Crary Mountains trachyte suggests that the volcanic rocks of this province are probably no older than Cretaceous.

Boudette found medium- to coarse-grained diorite resting unconformably beneath mafic volcanic rocks in the north end of the Executive Committee Range at approximate lat 76°00′ S.; long 124°00′ W. (fig. 4).

Although water-laid sediments are interstratified with the volcanic rocks of Marie Byrd Land, this is not proof that the volcanics predate the ice cap, for Boudette has found that melt water forms in areas where the atmospheric temperature does not usually rise above freezing. Moreover, the stratovolcano cones of Marie Byrd Land may have been offshore islands before their ice covers coalesced with the ice of the main plateau.

Geology of the Thurston Peninsula-Eights Coast regions

J. C. Craddock of the University of Minnesota, and H. A. Hubbard,[15] working in cooperation with the 1960 U.S. Bellingshausen Sea Expedition, found that bedrock in the easternmost part of the Thurston Peninsula (fig. 4) is a gneissic to massive, medium-grained diorite that contains schistose layers. This may correlate with the diorite found by Boudette in the Executive Committee Range. Planar structures in diorite on two offshore islets near the central part of the peninsula and on a nunatak near its western end strike northeast and dip 30° SE. Sandstone pebbles identified by Hubbard from dredgings off the coast of the Thurston Peninsula are not likely to have come from this crystalline rock terrane, and perhaps were carried long distances by ice rafting.

Coal in the Antarctic

Coal of probable Permian age is reported from eight widely separated localities along the trans-Antarctic mountains (fig. 4). The coal is approximately of semianthracite rank. According to J. M. Schopf (Schopf and Long, 1960), it reached this rank as a result of lithostatic loading beneath a great thickness of sediments deposited in a geosynclinal belt during late Paleozoic and early Mesozoic time. Although diabase sills, as much as 2,000 feet thick, are common in the coal-bearing sedimentary rocks of Victoria Land, the thermally metamorphosed coal does not show coking or shrinkage effects. Consequently, Schopf believes that the coal had essentially reached its present rank before the diabase intrusion.

High-rank coal is found within 200 miles of the South Pole in the central Horlick Mountains (approximately at lat 85°30′ S.; long 124° W.). Samples of this coal collected by W. E. Long and examined by Schopf contain fossil wood in which the annual growth rings are nearly a centimeter thick. These rings are comparable to those of rapid-growing trees in favorable sites in temperate climates. Schopf therefore concludes that the Permian climate of Antarctica was at least as warm as temperate.

Geology of the Taylor Dry Valley area

Warren Hamilton and Phillip T. Hayes, continuing studies related to their field work during the 1958–59 austral summer, attribute layering in a quartz disbase sill to upward migration of interstitial liquids. Lateral movement of partly differentiated magma resulted in complications of the layering structure.

In the same vicinity as the diabase sill Hamilton and Hayes (Art. 224) find the flowage of the Taylor Glacier (fig. 4) is mainly by shear along discrete planes near its base, and partly by pervasive laminar shear along foliation planes.

Granites of the Ross Sea region

A chemical comparison of the granites of the Ross Sea region by Warren Hamilton (Art. 225) has shown that the Cambrian(?) rocks of the oldest Paleozoic orogen, ranging in composition between quartz diorite

[15] Craddock, J. C., and Hubbard, H. A., 1961, Preliminary geologic results of the 1960 U.S. Expedition to the Bellingshausen-Amundsen Sea, Antarctica: Science, v. 133, no. 3456, p. 886–887.

and quartz monzonite, are relatively high in rare-earth elements. In contrast to these rocks, the younger Paleozoic(?) granodiorites and granites of West Antarctica (long 0° through 180° W.) are high in trace contents of chromium, copper, nickel, and tin. The rocks of the Palmer Peninsula of Cretaceous or early Tertiary age are dominantly quartz diorites.

Glacial geology of Antarctica

Continued studies of surficial deposits in the McMurdo Sound area (fig. 4) mapped by Troy L. Péwé (1960 a, b, c) during the 1957–58 austral summer demonstrate at least four major Quaternary glaciations. Algae dated by E. H. Olson and W. S. Broecker indicate that the age of the last glaciation is at least 6,000 years. A moraine with a core of dead ice, at least 6,000 years old and blanketed by 1 to 10 feet of vegetation-free drift, covers about 85 square miles and is the largest ever reported. The ice cores of similar moraines in temperate and subarctic latitudes are known to persist for only a few centuries. Recent work by Péwé has shown that the age of sand-wedge polygons in the McMurdo Sound area is directly proportional to the width of the overlying troughs; some wedges in the area have been determined by this relationship to be at least 1,000 years old. A dehydrated seal carcass collected by Péwé about 100 yards in front of the snout of the glacier in Davis Valley (fig. 4) is 200 to 500 years old as dated by Broecker, indicating that the glacier has not advanced beyond the position of the seal during this period.

GEOLOGIC AND HYDROLOGIC INVESTIGATIONS IN OTHER COUNTRIES

Under the auspices of the International Cooperation Administration, the Geological Survey is currently working with many other governments in geologic and water-resources investigations broadly directed toward advancement of national economies. A major objective of the program is to assist these governments in establishing or expanding locally staffed and managed organizations that will carry forward independent programs of work on mineral and water resources. In most countries this assistance includes consultation and advice, demonstration, and direct project activities. (See page A–139 for a list of current projects.) The following statements highlight new information acquired during the course of this work. Other new information acquired as a result of work in other countries is summarized on pages A–6, A–7, and A–83.

Thorium and rare-earth deposit, Brazil

A large deposit of thorium and rare earth at Morro do Ferro, which was discovered in 1953 as a result of airborne radioactivity studies by the U.S. Geological Survey, has been mapped and sampled by Helmuth Wedow as part of an exploration program sponsored by the U.S. Atomic Energy Commission in collaboration with the Brazilian National Research Council and the Departamento Nacional da Produção Mineral.

The country rock, deeply decomposed, is probably syenite-phonolite. A magnetite stockwork, probably representing a late stage in the cycle of alkaline intrusion, cuts the country rock. The mineralizing solutions containing thorium and rare-earth elements followed the emplacement of magnetite, enriching the highly fractured rocks and the borders of some of the magnetite veins.

Assays on unconcentrated material show a range of 0.13 to 3.77 percent equivalent ThO_2 and 1.5 to 21.13 percent total rare-earths oxide. The uranium content of these samples is generally in the range of 0.00X to 0.0X percent. Mineralogic study indicates that much of the thorium is present as thorogummite, although some occurs in allanite. The rare earth elements occur chiefly in the allanite and in the rare-earth fluocarbonate, bastnaesite.

Diamond deposits in Bahia, Brazil

Diamonds are produced on a small scale by primitive methods in two districts in Bahia—the Chapada Diamantina in the central part of the State, and the Lavras Diamantinas farther south. In both districts the diamonds are concentrated in local stream gravels. Recent geologic mapping in the Chapada Diamantina district by Max G. White and C. T. Pierson has shown that the diamonds are derived from beds of sandstone and conglomerate correlated with the Tombador series of Silurian age or younger, whereas it had been assumed previously that the source rock was the Lavras series of Precambrian or Early Cambrian age as in the Lavras Diamantinas district.

Uranium in the Serra de Jacobina, Bahia, Brazil

According to Max G. White, uranium and gold at Morro do Vento, south of Jacobina, in the Serra de Jacobina, occur in conglomerate and quartzite of Precambrian age. The deposits were formed by hydrothermal solutions introduced along a fracture or fracture zone. In the Main Reef, the principal deposit, the mineralized rock averages about two meters in thickness through a strike length of 1,260 meters. The zone of mineralized rock extends across quartzite and conglomerate beds, and its distribution is in no way controlled by lithology. Near the surface, the Main Reef contains an average of 0.0076 percent equivalent uranium oxide and 10.0 grams of gold per metric ton.

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Geologic studies of iron deposits of Brazil

Recent stratigraphic and structural studies of the Precambrian rocks in the iron district of central Minas Gerais by George C. Simmons and Charles H. Maxwell in cooperation with geologists of the Brazilian Departamento Nacional da Produção Mineral, has resulted in establishing the stratigraphic position of a thick sequence of rocks, including a very thick quartzite of great lateral extent, that had never been satisfactorily established by previous work in the area. The conclusions drawn from the study permit the solution of other general and specific structural problems, particularly in the underground mapping of the iron formations.

Chilean earthquakes of May and June 1960

Ernest Dobrovolny and R. W. Lemke studied the earthquake-damaged areas in southern Chile at the request of the Chilean Ministry of Public Works and the Instituto de Investigaciones Geológicas of Chile. The areas of excessive damage were found by mapping to be on alluvium, landslides, or artificial fill. Surface faulting was not observed although changes in elevation that occurred along the coast may be due to movement along a north-trending fault.

Origin of Chile nitrate deposits

Geologic field investigations of nitrate-bearing salt deposits of northern Chile by George E. Ericksen in cooperation with the Instituto de Investigaciones Geológicas of Chile have shown that geologic, physiographic, and climatic conditions of today are similar to those prevailing since the saline deposits started to accumulate, probably in Pleistocene time. The salts were derived by leaching of rocks, chiefly rhyolite tuffs, on the western slope of the high Andes where precipitation is appreciable. The salts are carried by surface and ground water and precipitated in closed basins on broad flats in the high Andes, the coast range, and intervening lower-lying areas. Chemical analyses of rhyolite tuff samples from two areas show a total soluble salt content of 0.1250 to 0.2705 percent, including the ions Cl, SO_4, NO_3, Na, Ca and K—the ones that are most abundant in the saline deposits.

Iron deposit in Libya

On behalf of the Ministry of National Economy of the United Kingdom of Libya, Gus H. Goudarzi has been engaged in studies of recently discovered sedimentary iron deposits in the Shatti Valley of Fezzan province in western Libya. The deposits have been explored by diamond drilling and by detailed geologic mapping of an area of about 3,500 square kilometers. The deposits are contained in beds and lenses at the base of a sequence of rocks of Early Mississippian age. The rocks are of shallow-water origin.

The iron-rich beds are intercalated with shale and siltstone. They are exposed for a distance of about 80 kilometers and average about 5 meters in thickness, with a maximum of about 11 meters. The ore is oolitic to finely granular. The oolites are chiefly hematite and to a lesser extent goethite embedded in a matrix of hematite and hematitic siltstone. Chamosite and siderite are present in small amounts, and limonite occurs as an alteration product. Petroliferous rock is associated with the iron deposit in most areas.

Minimum reserves of iron-rich rock indicated by diamond drilling are of the order of 700 million metric tons. Representative rock contains: Fe, 48.00; SiO_2, 16.61; P_2O_5, 0.62; S, 0.22; and Al, 3.25 percent.

Fluorspar deposits of Mexico

A survey of 12 major fluorspar districts in 9 States of Mexico by Ralph E. Van Alstine accompanied by Samuel Estrada and Ernesto de la Garza (Art. 226) indicates that reserves can sustain production for many years at the present rate. More than two-thirds of the deposits examined are in limestone of Early Cretaceous age. The others are in shale or volcanic rocks that overlie the limestone, within or next to intrusive Tertiary rhyolite, or in andesitic rock and phyllitic shale of probable Paleozoic age. The ore consists predominantly of fluorite, calcite, and quartz or chalcedony and is estimated to average 65 percent CaF_2. In some deposits the calcite content increases with depth. Small quantities of barite, celestite, gypsum, native sulfur, pyrite, sphalerite, galena, chalcopyrite, iron oxides, or maganese oxides are present in most of the ores. Fluorspar reserves in the districts visited are estimated to be about 5 million tons of measured and indicated ore and 10 million tons of inferred ore, averaging about 65 percent CaF_2.

Phosphorite deposits in Mexico

As part of a cooperative project with the Instituto Nacional para la Investigacion de Recursos Minerales of Mexico, Cleaves L. Rogers and Roger Van Vloten have mapped and sampled a large area of marine phosphorite in north-central Mexico.

The phosphorites are limited mainly to one member of the La Caja formation of Late Jurassic age and its nearshore equivalent, the La Casita formation. The richer phosphatic beds are composed mainly of apatite, calcite, and chert mixed in widely varying proportions. Most of the phosphate is primary, but some material has been dissolved and redeposited, probably under diagenetic conditions. Primary phosphate forms small, generally structureless, pellets and nodules ranging in size from 0.05 millimeter to about 3 centimeters. The phosphate mineral is carbonate-fluorapatite similar to that of the phosphorites in the Phosphoria formation. Reserves total about 77 million metric tons of phosphate rock averaging about 19 percent P_2O_5 and about 75 million tons of submarginal phosphate rock averaging about 14 percent P_2O_5.

Iron deposits in West Pakistan

An investigation conducted by Walter Danilchik, a member of the advisory team attached to the Pakistan Geological Survey, in cooperation with geologists of that organization, has revealed that a sedimentary iron formation of Early Cretaceous age in the Surghar and Western Salt Ranges, Mianwali district, West Pakistan, contains about 170 million tons of proved reserves averaging more than 29 percent iron (Art. 371). The formation grades eastward from glauconite to chamosite and limonite, possibly corresponding to a transition from marine to terrestrial environments during deposition.

The iron-rich stratum is in the upper part of the Chichali formation of Neocomian age. It consists of glauconitic sandstone having a maximum thickness of 200 feet. In the high elevations of the Surghar Range, the outcrops of the layer are generally continuous. In the Salt Range, the stratum is discontinuous and poorly exposed. Chemical analyses of a five-part channel sample across a 22-foot bed believed to be representative of the iron-rich stratum show the following percent averages: Fe_2O_3, 45.88; SiO_2, 26.08; Al_2O_3, 8.13; CO_2, 1.9; CaO, 0.68; Na_2O, 0.10; P_2O_5, 0.52; K_2O, 2.97; loss on ignition, 12.70.

Mineral resources of Taiwan

According to Sam Rosenblum, who is acting as advisor to the Geological Survey of Taiwan (Formosa), the mineral resource position of the island may be summarized as follows:

Reserves of bituminous coal, much of which is of coking quality, total about 200 million metric tons. Reserves of marble, dolomite and clay are large, but high-grade ceramic clay is scarce. Reserves of native sulfur totaling 3 million metric tons and reserves of pyrite totaling 800,000 tons have been located in the volcanic region of north Taiwan. Volcanic material suitable for use as concrete aggregate is abundant in this part of the island.

Metalliferous deposits are few. Copper and gold in the Chin-Kua-Shih mine in northeastern Taiwan are in veins and stockworks in and adjacent to a dacite stock. Several small vein deposits of pyrite, chalcopyrite, and pyrrhotite are found in the metamorphic rocks, and one small manganese deposit has been mined.

New deposits of fluorite and manganese in Thailand

Louis S. Gardner and Roscoe M. Smith, who are acting as advisors to the Royal Department of Mines of Thailand, report that fluorite has been discovered in commercial quantities in Chiengmai and Ratburi, two widely separated provinces along the orogenic belt that extends from the Himalaya mountains southward through the Malay peninsula. The deposits are veins as much as 4 meters wide and 300 meters long in granite. The ore shoots are as much as 50 meters long. Smaller occurrences elsewhere along the same belt suggest that other deposits of commercial size and grade may be present.

The discovery and continued successful exploration of battery-grade manganese in Loei province has stimulated prospecting throughout northern Thailand. A new manganese district has been discovered in Lamphun province, and several deposits are in various stages of development and exploration. The new deposits are iron- and manganese-enriched laterites on remnants of a terracelike plateau on the periphery of the Chiengmai and Li valleys.

Surface-water resources of the Helmand River, Afghanistan

An investigation of the surface-water resources of the Helmand River watershed in southwestern Afghanistan has been in progress since 1952, with active participation of Survey hydrologists. A basic network of 16 stream-gaging stations, 3 meteorological stations, and 2 stations for the collection of suspended sediment, has been established. Stream-flow and other hydrologic data obtained from these stations are compiled, analyzed, and published periodically to guide (a) the adjustment of the inflow-outflow balance in reservoirs in the watershed to downstream water requirements, (b) the division of available water in distributary irrigation canals, and (c) the apportionment of water in the Chakhansur Basin between Afghanistan and Iran.

Ground water in the Libyan Desert, western Egypt

A detailed investigation of the regional ground-water hydrology of five oasis depressions in the Libyan Desert of western Egypt was begun in 1960 by the General Desert Development Authority with the participation of a Survey hydrogeologist. Work to date indicates that the region is underlain by thick and productive sandstone aquifers containing water under artesian pressure.

River basin surveys in Iran

River basin surveys in Iran, in progress since late 1953 by U.S. Geological Survey hydrologists cooperating with the Iranian Hydrographic Service of the

Independent Irrigation Corporation, have led to the establishment of a nation-wide network of about 200 stream-gaging, quality of water, and sediment sampling stations. Most of the stations are maintained and operated on a continuing basis. The hydrologic records from these stations have been published annually in English and Farsi since 1954 in Hydrographic Yearbooks that are widely used in Iran's 7-year Plan and elsewhere for water-resources development and management.

EXTRATERRESTRIAL STUDIES

Geological research in support of space exploration, begun in 1959 by the Geological Survey, was expanded in 1961 on behalf of the National Aeronautics and Space Administration. Three lines of research were followed in 1961: photogeologic mapping of the Moon, investigation of terrestrial meteorite craters and impact phenomena, and investigation of extraterrestrial materials.

PHOTOGEOLOGIC MAPPING OF THE MOON

Photogeologic mapping of the Moon has been carried out primarily with photographs obtained from the Lick, Pic du Midi, Mount Wilson, McDonald, and Yerkes Observatories. A generalized photogeologic map of the entire subterrestrial hemisphere of the Moon, at an approximate scale of 1:3,800,000, was completed for the Office of the Chief of Engineers, U.S. Army by R. J. Hackman. Preliminary maps of the stratigraphy and structure have been prepared for the National Aeronautics and Space Administration at a scale of 1:1,000,000 in the general target area for a number of hard landing lunar capsules to be launched as part of the Ranger project.

Lunar stratigraphy and time scale

Five major stratigraphic subdivisions of the lunar crust have been recognized by E. M. Shoemaker and R. J. Hackman (1960) during the course of detailed photogeologic mapping. In descending order these subdivisions include: (a) rays and the rim deposits of ray craters (the Copernican System), (b) rim deposits of certain craters that resemble ray craters but are unaccompanied by rays (the Eratosthenian System), (c) material of the maria floors (the Procellarian System), (d) a great sheet of material associated with Mare Imbrium and the rim deposits of certain craters superimposed on this sheet (the Imbrian System), and (e) rim deposits and floor material of craters on which the Imbrian sheet is superimposed (pre-Imbrian material). A lunar time scale corresponding to these five stratigraphic subdivisions has been adopted as follows:

Present time
- Copernican Period
- Eratosthenian Period
- Procellarian Period
- Imbrian Period
- pre-Imbrian time

Beginning of lunar history

Statistical studies of the distribution of Eratosthenian and Copernican craters on the Procellarian System suggest that the uppermost part of the Procellarian System is about the same age wherever it occurs. Comparison of the crater frequency distribution with the number and age of terrestrial impact structures and the present observed rate of meteorite infall suggests that the Eratosthenian and Copernican Periods, taken together, represent the greater part of geological time. The Copernican Period appears to represent somewhat less that half of this total interval. If this is so, the Procellarian and earlier periods represent comparatively short intervals of time, but intervals of considerable activity in the development of the lunar surface features.

Photometric investigations by W. A. Fischer and T. M. Sousa of the Kepler and Copernicus region of the Moon show that each major stratigraphic unit is characterized by a certain limited range of albedo. The ranges of albedo of different systems overlap, but there is generally a distinct change at the contacts.

The thickness of the Procellarian System in the Letronne region of the Moon has been estimated by C. H. Marshall (Art. 361) by reconstructing the topographic surface buried by the Procellarian on the basis of exposed remnants of pre-Procellarian crater rims. The Procellarian covers 240,000 square kilometers in the Letronne region and averages about 1.1. kilometers in thickness, somewhat less than twice the mean thickness of the Deccan traps of India or the Columbia Plateau basalts, which cover comparable areas.

Structural features

Most of the larger Copernican and Eratosthenian craters exhibit the form and detailed surface features expected for meteorite impact craters. Their raised rims have been interpreted as having been formed by deposits of ejecta, and the crater floors (by analogy with terrestrial impact craters) should be underlain by deep deposits of breccia. Terraces and scarps on the walls of the larger craters appear to have developed by inward slumping of the crater walls; the scarps are interpreted as the traces of normal faults that bound the individual slump blocks. Other large isolated scarps on the lunar surface have the form of normal fault scarps and have been so mapped by R. J. Hackman.

Small craters alined in rows or chains (in some places with interspersed small domes) closely resemble in size, form, and alinement the maar type of terrestrial volcano. In places the crater chains pass into deep narrow trenches, termed "rilles." Elsewhere, rilles may have only a few associated craters or may be unaccompanied by craters. The rilles are probably diverse in origin. Some may be formed over elongate, dikelike diatremes; some may be more closely analogous to the Icelandic gjá, great fissures in basaltic lava fields; and others may be long, narrow graben.

Topographic forms characteristic of the Procellarian System include ridges and low conical to dome-shaped hills. Individual ridges are typically 15 to 30 kilometers long, and they occur both singly and in complex en echelon systems as much as several hundred kilometers in length. The ridges are probably the loci of anticlines in the Procellarian, but the causes of the buckling are not known. Many of the ridge systems are parallel with the margins of the maria or with buried highs on the pre-Procellarian topography. Many of the low conical and dome-shaped hills exhibit small craters, and thus resemble small terrestrial shield volcanoes according to Hackman.

In addition to these individual features, the Moon's surface is characterized by a larger system of linear forms that may be controlled by a tectonic fabric or network of faults and fractures. The most conspicuous element of this network, originally referred to by G. K. Gilbert as Imbrian Sculpture, is a system of scarps, ridges, and valleys that radiate from a point in the Mare Imbrium.

TERRESTRIAL METEORITE CRATERS AND IMPACT PHENOMENA

The characteristics of impact craters and the mechanics of cratering and other phenomena of high speed impact are of fundamental importance in understanding the surface of the Moon because the lunar surface has been subjected to continuous bombardment by high speed particles and meteoroids.

Terrestrial meteorite craters

Detailed mapping (Shoemaker, 1960) and petrographic investigation (Chao, Shoemaker, and Madsen, 1960) of Meteor Crater, Ariz., have indicated several possible structural and mineralogic criteria for the recognition of craters or structures produced by meteorite impact. Significant advances were made in 1961 in the application of these criteria. The suggestion that natural coesite (first discovered at Meteor Crater, Ariz.) is diagnostic of the occurrence of high shock pressures was strengthened by demonstration of its presence in fractured sandstone collected by V. E. Barnes of the University of Texas from a second meteorite crater, 300 feet in diameter, at Wabar, Arabia (Chao, Fahey, and Littler, 1961). In addition, J. J. Fahey and Janet Littler were successful in identifying coesite in samples of strongly shocked alluvium collected by E. M. Shoemaker from the Teapot Ess nuclear explosion crater, a crater at the Nevada Test Site of nearly the same diameter as the Wabar Crater.

Following the initial discovery of coesite, E. M. Shoemaker visited and collected samples from the Ries Basin in Bavaria, Germany, a crater 17 to 18 miles in diameter for which some German and other geologists have suggested an impact origin. The basin yielded samples of suevite, a breccia that Shoemaker interprets as formed by fallout of ejected shocked debris, by analogy with similar breccia at Meteor Crater, Ariz. These samples were found by E. C. T. Chao to contain (a) coesite, (b) lechatelierite (silica glass), an important phase in rocks in the fallout at Meteor Crater, and (c) a pyroxene closely similar to one that occurs in sintered Meteor Crater materials (Shoemaker and Chao, 1960). Partially sintered fragments of crystalline rocks in the suevite commonly contain in a single specimen several widely different kinds of glass—as would be expected from fusion of polymineralic rocks by shock. The shape of the Ries crater, occurrence of imbricate thrust sheets on its walls and rim, and the distribution of various types of breccia in and outside of the crater appear to have a straightforward explanation in terms of impact mechanics. The Ries is the largest terrestrial crater for which substantial evidence of impact origin has now been accumulated.

A fourth natural crater from which coesite has been identified by Janet Littler and E. C. T. Chao occurs at Lake Bosumtwi in Ghana. This crater, which is 5 miles in diameter, is the second largest crater in the world for which fairly definite evidence of impact origin has now been obtained.

At Sierra Madera, Tex., Eggleton and Shoemaker (Art. 342) have found a lens of breccia, 1½ miles across and possibly as much as 2,800 feet deep, nested in a collar of steeply upturned and overturned beds. By analogy with Meteor Crater, Ariz., the breccia at Sierra Madera is believed to have once underlain an impact crater about 2 miles in diameter.

Impact phenomena

High speed impact of projectiles fired at the Ames Research Center into different types of rocks has produced craters with various structural features. Inward sloping walls formed by spalling and a central zone of crushed rock are common to all the experimental craters. Small shatter cones were produced in a block of dolomite from the Kaibab limestone (Permian) by impact of an aluminum sphere traveling at 18,400 feet per second (Shoemaker, Gault, and Lugn, Art. 417). The lower limiting shock pressures under which the cones are formed are of the order of 1 to 4 kilobars. H. J. Moore has found that the penetration of the high speed projectiles increases roughly in proportion to the momentum, whereas the volume of the crater is a discontinuous function of the energy. The craters grow radially by the separation of discrete concentric spalls.

A 0.4 gm steel sphere fired at 4.3 kilometers (14,000 feet) per second into a block of Coconino sandstone (Permian) was both fragmented and partly fused, contrary to expectations from hydrodynamic theory. D. E. Gault,[16] H. J. Moore, and E. M. Shoemaker have shown that the fusion can be accounted for partly by conduction of heat from the shocked sandstone into the steel and partly by frictional heat produced along shear planes during breakup of the projectile.

Low-speed impact of an armor piercing bullet was found by Roach, Johnson, McGrath, and Spence (Art. 272) to produce marked changes of thermoluminescence in a block of marble. The changes in thermoluminescence vary smoothly with distance from the path of penetration of the bullet. Systematic variations in thermoluminescence have also been found by Roach in the rocks from several formations in the walls and ejected debris at Meteor Crater, Ariz. The variations in the thermoluminescence of the Kaibab rocks at Meteor Crater are similar to those produced at the Ames Research Center by high-speed impact of projectiles fired into a block of dolomite from the Kaibab.

EXTRATERRESTRIAL MATERIALS

Much of our knowledge of other bodies in the solar system is derived from pieces of these bodies that arrive on the Earth in the form of tektites and meteorites.

Tektites

The discovery by E. C. T. Chao of nickel-iron spherules in some tektites from the Philippine Islands strongly suggests that the tektites are related to the impact of meteorites. This evidence, together with calculations by D. R. Chapman of the Ames Research Center on the entry velocity of Australian tektites into the Earth's atmosphere, indicates that these siliceous glassy objects are probably products of large meteorite impacts on the Moon.

[16] Ames Research Center, National Aeronautics and Space Administration.

In a study of the geologic age and stratigraphic occurrence of the tektites of Texas (bediasites), E. C. T. Chao and Bettie Smysor have determined that nearly all have come from red, chrty gravel that lies on the Jackson group of Eocene age. The gravel may be derived from the Jackson group or it may be a lag accumulation from the younger Catahoula formation. The latter interpretation is in better agreement with a reported K^{40}/A^{40} age determination of 29 million years for the tektites.

The bulk specific gravity of bediasites determined by Chao, Smysor, and J. L. Littler shows a weak positive correlation and definitely non-random relation with the mass of the specimens. This relation is probably controlled by composition, as indicated by the strong correlations between specific gravity and refractive index and between refractive index and silica content. The presence of possible crystalline phases is suggested by weak reflections recorded on X-ray films.

Partially monitored high-precision analyses have been made by Frank Cuttitta and M. K. Carron for the major constituent elements of the bediasites. Among different specimens the total alkalies increase with silica, whereas alumina, ferrous iron, and titania decrease with increase in silica. The variations of the principal constituents are of the type that would result from fractional volatilization of a melt of tektitic composition.

The metallic spherules discovered by Chao in the Philippine tektites range in diameter from 20μ to 0.8 mm and are scattered through the interiors of the individual specimens. Electron probe and X-ray fluorescence analyses by Isidore Adler and E. J. Dwornik have shown that the composition of the spherules is about 95 percent iron and 2 to 3 percent nickel. Chao has found by X-ray diffraction that the principal phase present in the spherules is kamacite (α iron), but that there is a second phase of undetermined composition, probably an iron phosphide, visible also in polished section. It is highly probable that the spherules are derived from meteoritic nickel-iron, and their size and distribution in the tektites resembles the size and distribution of nickel-iron spherules in glasses of known impact origin.

By fusing several types of rocks in a solar furnace Friedman, Thorpe, and Senftle (1960a, b) have shown that melts of tektitic composition might be formed from these rocks only if they were melted at temperatures in excess of 2,500° C or heated at this temperature for periods in excess of 20 minutes. The ferric-ferrous iron ratio of the fused rocks compared to that of tektites suggests that any atmosphere in which tektites were melted had a partial pressure of oxygen less than that on the surface of the Earth. Changes in the magnetic properties of the rocks produced by fusion indicate that a heating period of 15 to 20 minutes at 2,500° C is sufficient to produce magnetic properties similar to those of tektites.

Meteorites

Electron probe analysis of minute schreibersite crystals in a Canyon Diablo iron meteorite by Adler and Dwornik (Art. 112) has shown that the nickel content of the individual crystals varies widely and does not appear to be related to the enclosing meteorite phases. The schreibersite crystals were evidently not in equilibrium at the time they were formed or else the equilibrium conditions were variable.

INVESTIGATIONS OF GEOLOGIC AND HYDROLOGIC PROCESSES AND PRINCIPLES

Investigation of geologic and hydrologic processes and principles is prompted by (and contributes to) the programs of resource and regional investigations described in previous chapters. Whereas the resource and regional investigations are stimulated largely by economic objectives, or by the need to know more about the geology of specific areas, the investigations of processes and principles are intended to provide new methods and tools needed for the continued advancement of the geologic and hydrologic sciences. These investigations are topical in nature as described below.

PALEONTOLOGY

Paleontological studies that have to do mainly with regional problems are described in other sections of this report. Findings that have to do with evolution, ecology, systematic biology, and other subjects of general interest are reported here.

Evolution

As a part of a study of fusuline zonation in the Toana Range, Nev., R. C. Douglass has recognized at least three lineages in the subfamily Schwagerininae. In one lineage, the genus *Triticites* gives rise to *Pseudoschwagerina* through a gradational series; in another, *Schwagerina* and *Paraschwagerina* are developed; the third lineage develops *Parafusulina*.

Comparison of inter- and intra-colony variation in rugose corals from the Onondaga limestone in New York by W. A. Oliver, Jr., has shown that the positive correlation between diameter and number of septa is not invariable. The data suggest that number of septa may be genetically controlled. Intercolony variation is greatest in stratigraphic units that include the largest number and variety of associated corals.

N. J. Silberling's restudy of Middle Triassic mollusks from Fossil Hill, Humboldt Range, Nev., from which most of the fauna described in J. P. Smith's monograph on Middle Triassic fossils was obtained, demonstrates the presence of nearly a dozen successive upper Anisian faunas. Stratigraphically controlled populations show a wide range of morphologic variation in some species of ammonites, and illustrate the evolutionary gradation from one species to another in the section.

Paleoecology

Stratigraphic study of Ordovician rocks on the Nevada Test Site by R. J. Ross, Jr., working with F. M. Byers, H. Barnes, and F. G. Poole (Art. 189), has led to the recognition of sizeable bioherms in the upper part of the Pogonip group. These are correlative with a larger bioherm recognized earlier in the year by Ross (Art. 97) during similar study in conjunction with mapping by H. R. Cornwall and F. J. Kleinhampl (1960a) in the Bare Mountain quadrangle of southern Nevada. Preliminary analysis suggests that the limestone in the bioherms may run as high as 95 percent $CaCO_3$.

E. R. Applin reports that planktonic foraminiferal species in clastic Paleocene strata from the subsurface of western Florida indicate a habitat that had open access to the sea. A marked reduction in the number of planktonic forms and the absence of certain planktonic species among the fauna in the Paleocene beds exposed in Alabama is believed to be due to a restricted, shallow-water marine habitat that was unfavorable to the floating forms.

Samples from the Citronelle formation and from the underlying Pascagoula clay of Florida, collected by O. T. Marsh, have been analyzed for pollen by E. B. Leopold. Pollen assemblages from the base, middle, and top of a 340-foot measured section of Citronelle formation, represent essentially the modern upland vegetation of west Florida. Of 40 forms identified from pollen and spores, all now grow locally except 3, and these are northern plants (spruce, hemlock, and *Dirca*), suggesting a cooler-than-present climate. No pollen could be found in the type section of the Citronelle in Alabama. The pollen flora of the Pascagoula clay (of late Miocence age, according to evidence from gastropods) represents a coastal swamp vegetation like the modern one except that of the 36 forms identified, 2 are now exclusively Asiatic trees (*Pterocarya*, *Eucommia*). In the Pascagoula flora no evidence of spruce, hemlock, or *Dirca* has yet been found. Sediments from a leaf locality at Red Bluff, Ala., described previously by Berry[17] as belonging in the Citronelle formation,

[17] Berry, E. W., 1917, The flora of the Citronelle formation: U.S. Geol. Survey Prof. Paper 98–L, p. 193–208.

contain a pollen flora identical to that of the Pascagoula clay. From the pollen data, two stratigraphic conclusions are possible: (a) evidence from pollen supports a Quaternary age for the Citronelle deposits in west Florida, bearing out the suggestions of Fisk[18] and MacNeil[19]; (b) the Red Bluff, Ala., leaf locality probably is not part of the Citronelle formation; therefore, leaves from it enumerated by Berry do not pertain to the age of the Citronelle. The second conclusion agrees with Roy's[20] field interpretation of the Lambert leaf locality which contains essentially the same flora as the Red Bluff locality.

More than 60 genera of plants have been identified by R. A. Scott, from the numerous seeds, wood, and pollen found in the Clarno formation (Eocene) of Oregon. The tropical to subtropical environment suggested by this flora is in keeping with earlier conclusions regarding the early Tertiary floras of western United States, based on studies of fossil leaves. In contrast to the leaf assemblages whose affinities are thought to be predominantly with tropical regions of the New World, the Clarno flora contains a high proportion of forms related to modern plants from tropical regions of the Old World.

Systematic paleontology

Studies by W. H. Bradley, of a very fossiliferous oil shale lamina of the Green River formation, have revealed a large and varied flora of microscopic algae and fungi. Three and perhaps four of the minute but well-preserved algae are so unlike living forms that they may represent new families.

Three new coral faunas of Silurian age from Maine and Quebec, described by E. C. Stumm and W. A. Oliver, Jr., are a mixture in approximately equal proportions of North American, European (new to North America), and cosmopolitan forms.

The Paleozoic species of *Bairdia* and related genera of ostracodes have been critically examined and revised by I. G. Sohn (1960b) in a monographic study that includes identification keys and stratigraphic range charts of genera and species. Publication of this study makes available for stratigraphic use this group of fossils.

In the last two years F. C. Whitmore, Jr., and C. A. Kaye have collected several hundred fossil specimens from Tertiary deposits at Gay Head, Martha's Vineyard, three miles off the Massachusetts coast. These and earlier collections include mollusks, crustaceans, porpoise, primitive whalebone whale, sperm whale, seal, sharks' teeth, and rhinoceros from the Miocene greensand, and mollusks and the astragalus of a horse from the Pleistocene sands and conglomerates. The Miocene greensand appears to be equivalent to the Kirkwood formation of New Jersey and to the Calvert formation of Maryland. It can probably be placed in the Arikareean and Hemingfordian provincial ages of North America and the Burdigalian of Europe. The best fossil for intercontinental correlation is the crab *Lobonotus*, which occurs in the Burdigalian, Helvetian, and Tortonian of the Vienna Basin. An important find from the Miocene greensand was a claw of *Homarus*, the genus to which the modern American lobster belongs. This genus had not previously been reported from deposits older than the Pleistocene.

Morphology

W. J. Sando (1961) has made a detailed study of ontogenetic trends in a population of *Ankhelasma typicum* Sando, a coral from the Mississippian Brazer dolomite of Utah. Changes in 6 morphologic characters were traced through 11 growth stages distinguished by the number of major septa. The analysis suggests that curvature of the corallum and flattening of its convex side are due to genetic factors associated with maintaining negatively geotropic growth and stability after toppling from an erect, apically attached position. Derivation of hypothetical growth curves suggests a progressive logarithmic decrease in the growth rate during ontogeny.

Stratigraphic paleontology

Studies by Mackenzie Gordon, Jr., of fossiliferous sections in the Confusion Range and Burbank Hills of western Utah that had earlier resulted in recognition of 4 major Upper Mississippian goniatite zones in the Chainman shale, now permit the division of each of 3 of these zones into 2 subzones. The 2 uppermost subzones of this sequence have also been recognized in southeastern California. The uppermost one occurs in the Chainman shale of the Inyo Range and Rest Spring shale of the Panamint Range, and the lower one, at the top of the Perdido formation in the Panamint Range.

An extensive collection of external molds of a diversified molluscan fauna has been obtained by N. F. Sahl from a section of the Upper Cretaceous Mount Laurel sand about 1.2 miles east-northeast of Arneytown, Monmouth County, N.J. Aside from the normally well-preserved oysters and belemnites this formation in the past has usually yielded only indeterminable internal molds of other mollusks. Many of the genera represented in the new collections have not been reported

[18] Fisk, H. N., 1945, Pleistocene age of the Citronelle [abs.]: Geol. Soc. America Bull., v. 46, no. 12, pt. 2, p. 1158–1159.

[19] MacNeil, F. S., 1950, Pleistocene shore lines in Florida and Georgia: U.S. Geol. Survey Prof. Paper 221–F, p. 95–107.

[20] Roy, C. J., 1939, Type locality of the Citronelle formation, Citronelle, Alabama: Am. Assoc. Petroleum Geologists Bull., v. 23, no. 10, p. 1553–1559.

previously in New Jersey. The presence of such species as *Anomia perlineata* Wade, *Venericardia subcircula* Wade, *Pseudomalaxis ripleyana* Harbison, *Fusinus macnairyensis* Wade and others suggests a close affinity with the Ripley fauna of Coon Creek, Tenn. This upper part of the Mount Laurel sand seems to lie within the upper part of the *Exogyra cancellata* zone.

Study by W. A. Cobban and G. R. Scott of about 1,000 collections of fossils from the Pierre shale of the Front Range and adjoining areas shows that *Inoceramus* and some other mollusks are useful in zoining the Pierre shale, although few are as restricted in range as the ammonites. Cobban has revised the sequence of straight ammonites (baculites) from the lower part of the Montana group and has recognized many new zones.

C. B. Hunt and A. P. Hunt (Art. 81) have recognized four stratigraphic-archeologic stages that are useful to the geologist studying latest Pleistocene and Recent sediments in the southwestern States. The stages are defined by a succession of atlatl or spear point-basketry and arrow point-pottery associations.

GEOMORPHOLOGY

The study of present-day land forms and geomorphologic processes is an integral part of geologic and hydrologic studies because the earth-shaping processes of the present may affect the works and plans of man and because they provide clues to the processes of the past. A representative selection of studies in geomorphology is summarized below. Others are summarized under regional headings, particularly on page A–31.

Lateritic saprolite in Puerto Rico

In the course of geologic mapping in east central Puerto Rico R. P. Briggs (1960) found that lateritic saprolite was developed on various volcanic rock types on relatively flat surfaces in a terrain that otherwise has great local relief. These relatively flat areas are believed by Briggs to be remnants of Miocene erosion surfaces now deeply incised; they occur largely in the range of altitude between 550 and 650 meters. Lateritic saprolite was found at altitudes as high as 850 meters at a few places in the western part of the area.

Chemical analyses made of a profile that grades downward from lateritic saprolite into fresh volcanic breccia demonstrate that laterization was the result of leaching by meteoric waters and was not caused by a fluctuating water table.

Interpretation of desert varnish

According to C. B. Hunt (Art. 81) desert varnish is rare on surfaces less than 2,000 years old as dated by archaeological remains and structures. Because desert varnish can form only on surfaces that are frequently wet, he believes that most of the varnish seen in arid regions formed during pluvial periods of the late Pleistocene.

Surficial geologic processes related to volcanoes

D. R. Crandell and D. R. Mullineaux working in the Toutle River Valley north of Mount St. Helens Volcano, Wash., have studied and mapped flows of volcanic debris that owed their mobility at the time of formation to steam and water. The flows apparently had anomalous temperatures of more than 100° C. One bomb-bearing flow contains abundant wood fragments with at least one stump still rooted in the underlying alluvium. Some wood is charcoal throughout, but the rooted stump and some of the fragments are charred only where in contact with the bombs.

The debris flow probably originated on the flank of the snow-covered volcano during an eruption as a hot avalanche. Melting snow that was converted to steam probably added to the mobility of the avalanche, and wood incorporated at this stage was converted to charcoal. Cooling during continued downslope movement may have permitted a direct transition from a hot, essentially dry avalanche to a water-mobilized debris flow, cool except for included bombs that retained enough heat to char the wood with which they came in contact.

Microrelief features in arctic regions

On Latouche Island near Baldez, Alaska, pools with raised rims occurring in sedge meadows have been described by H. T. Shacklette (Art. 355). The pools occur on impervious glacial deposits and are believed to form where small streams are dammed by the growth of sedges. The pools are enlarged by ice push and a ridged, furrowed, and hummocky microrelief is eventually produced.

Large rectangular polygons 25 to 60 feet in diameter were found by W. E. Davies (Art. 366) in bedrock at Brønlund Fjord in north Greenland. The polygons are developed in gently dipping dolomitic bedrock on smooth glaciated surfaces with low relief. The polygons are bounded by ridges of rubble up to 12 inches high and thrust slabs 4 feet high. They are believed to have formed by frost heaving in a manner similar to polygons in unconsolidated deposits.

Geomorphology of permafrost

Studies in the Fairbanks area, Alaska, by Troy L. Péwé indicate that periods of permafrost and loess formation have alternated with periods of deep erosion; these events can probably be correlated with glacial and interglacial stages. The evidence indicates that the existing perennially frozen ground in the area is no older than Wisconsin.

Morphology of stream channels

Sediment characteristics affect the morphology of stable alluvial channels through their effect on resistance to erosion as well as by their depositional behavior. S. A. Schumm (1960a) found that in alluvial streams containing only small amounts of gravel the width-depth ratio decreases with an increase in the silt-clay content of bank and bed material. He showed also (1960b) that fine-grained cohesive sediments tend to adhere to channel banks, forming stratification planes concave upward. Noncohesive sediments tend to be deposited directly on the channel floor, resulting in horizontal stratification in the fill.

By studies of the relation of lithology to hydraulic and physical characteristics of stream channels in central Pennsylvania, L. M. Brush, Jr., (1961) found that particle-size changes along a stream show no consistent relation to channel slope. Tributary entrance and parent material were most important determinants of particle size. Downstream change in particle size was found to be much greater in some streams than could be attributed to abrasion or wear.

Studies in northeastern Arizona by R. F. Hadley (Art. 156) show that the shape of stream channels is influenced by the growth of saltcedar, which is effective in causing deposition along the banks and on the flood plain. Saltcedar plants grow most abundantly along the high-water line in stream channels, and on flood plains. If low flows persist for a few years the seedlings grow to considerable size. Observations over a 2-year period showed that saltcedar grew about 1.5 to 2 feet per year. During this same period the channel depth increased 0.2 foot; the channel slope increased 0.0005 foot per foot, and channel width decreased 3.1 feet. Hadley believes that deposition induced by growth of saltcedar will result in progressive reduction of channel width until all floods overtop the banks.

Mechanics of meandering and irregular channels

The magnitude and type of energy losses caused by channel curvature alone were found by L. B. Leopold and others (1960) to depend upon the ratio of channel width to bend curvature below a threshold value of Froude number for the whole channel. At Froude numbers above this threshold, energy losses increase rapidly with velocity. A channel bend having a relatively large value of the ratio width: radius, but still within the range of values observed in natural channels, can cause energy losses several times that resulting from boundary friction in a straight channel that is otherwise similar.

Leopold and M. G. Wolman (1960) compiled evidence indicating that curves in natural stream channels exhibit a relatively narrow range of the curvature ratio width: radius. A large percentage of bends have values lying roughly between 0.5 and 0.3. R. A. Bagnold (1960) demonstrated that this range of values represents a condition of minimum energy loss in curved channels, an observation well known in the study of pipe bends. At the observed value of this ratio there is formed near the convex bank of the curve an eddy that restricts the effective width of channel, and (under a narrow range of conditions) minimizes energy loss.

Effective force in geomorphology

The relative importance in geomorphic processes of extreme or catastrophic events and more frequent events of smaller magnitude can be measured (a) in terms of the relative amounts of "work" done on the landscape and (b) in terms of the formation of specific features of the landscape.

M. G. Wolman and J. P. Miller[21] have shown that the largest portion of the total sediment load in rivers is carried by the relatively frequent events of smaller magnitude. In smaller basins and in drier regions the relative importance of catastrophic events appears to increase. Equilibrium landforms such as sand dunes and beaches may similarly be related to both magnitude and frequency of stress.

Geomorphology related to ground water

Because the natural movement of water into and out of the ground depends on the forms of the land, many problems concerning water supply, radioactive-waste disposal, and engineering geology may be solved through study of geomorphology.

H. E. LeGrand has shown that the general coincidence of surface and subsurface drainage patterns in many humid terrains allows a quick appraisal of (a) rates and directions of ground-water movement, (b) maximum limit of recharge, and (c) maximum limits of withdrawal from wells.

The influence of local details of geomorphology on ground-water occurrence in alluvial deposits adjacent to mountain fronts in southern Arizona is being studied by Leo Heindl. In this area ground-water yields from wells vary considerably within short distances. Areas of low yield are roughly triangular in shape, with apices away from the mountain front. Because their location and shape are analogous in part to areas of low rainfall, called "rain shadows," areas of low yield are called locally "ground-water shadows." These ground-water shadows occur (a) between alluvial deposits laid down by two large washes cutting through the Gunnison Hills in the Wilcox basin, and (b) in the floodplain deposits of the Santa Cruz River in the vicinity of a

[21] Wolman, M. G., and Miller, J. P., 1960, Magnitude and frequency of forces in geomorphic processes: Jour. Geology, v. 68, no. 1, p. 54–74.

gap in the De Bac Hills, south of Tucson. Here, apparently, the shadows represent areas of predominantly fine-grained deposition outside the main courses of the channel as it swings through the gap.

Geomorphology and geology in relation to streamflow

Gains or losses in discharge usually occur where stream and lake beds intersect regional aquifers. In a study of water resources in the eastern Kentucky coal field, carried on in cooperation with the State of Kentucky, G. A. Kirkpatrick, W. E. Price, E. L. Skinner, and others have found that, in general, streams draining the relatively impermeable rocks of the Breathitt formation have lower base flows per unit area than those cutting into the more permeable sandstones of the underlying Lee formation. In a study near San Antonio, Tex., carried on in cooperation with the State of Texas, S. Garza reports that significant amounts of stream water disappear underground at points where the streams cross the outcrop of the Edwards and associated limestones in the Balcones fault zone. This water is the principal source of recharge to the limestone aquifer supplying the San Antonio area.

In a study of Navajo Lake, in southwestern Utah, H. E. Thomas and M. T. Wilson have determined that discharge from the lake supplies water to two major drainage basins—the Sevier River and the Virgin River—by means of subsurface flow through sinks developed by solution in limestones of probable Eocene age. Controlled tests using a discharge-time function and fluorescin dye established the following relations: At intermediate to low stages of Navajo Lake, as much as 40 percent of the discharge may reach Cascade Spring, in the headwaters of the Virgin River, with the remainder going to Duck Creek Spring in Sevier River drainage. However, at high stages of Navajo Lake, the sinks through which Cascade Spring is supplied act as a choke and only about 15 percent of the total discharge reaches the spring.

PLANT ECOLOGY

The distribution of plants is influenced in part by geologic and hydrologic environments and the distribution of certain species and assemblages may be indicative of environment. For this reason plant ecology is receiving increased attention by geologists and hydrologists.

Relation of vegetation to soil moisture and texture

Field studies of grassland vegetation and soil near Palo Alto, Calif., and Golden, Colo., by F. A. Branson and others indicate that the distribution of species and quantity of vegetation are related to soil moisture and texture. A greater variety of species and denser stands, in vegetation composed primarily of exotic annual plants, grow on sandy soils than grow on nearby clayey soils near Palo Alto (Art. 76). Although soil moisture at saturation and field capacity is much lower in the sandy soils, they believe that the higher infiltration rates and larger quantities of water available to the plants are factors favoring the denser vegetation on sandy soils. In perennial grassland vegetation near Golden, more species grow on stony soil than on shale-derived soil (Art. 239). Species characteristic of prairie vegetation of eastern Nebraska and Iowa are abundant on the stony soil, whereas species characteristic of the mixed-prairie below 6,000 feet in altitude in central and northern Great Plains are predominant on the shale-derived soil. Higher infiltration rates, higher soil-moisture quantities throughout the growing season, and lower soil-moisture tension in the stony soil indicate that a greater quantity of available water is responsible for the differences in vegetation.

Trees as indicators of floods

Evidence of past floods and sedimentation on flood plains has been found by R. S. Sigafoos in the form and wood anatomy of trees knocked over by the floods or partly buried by alluvium. Some trees knocked over by the less frequent large floods are not killed, and vertical sprouts soon grow from the inclined trunks. The age of these sprouts is equal to the number of growing seasons since the tree was knocked over. Trees that are partly buried by deposition of alluvium during floods develop wood in the buried part of the trunk that grows more like root wood than the parent trunk wood. The change is distinct, and elements of the wood can be measured to determine the year of deposition.

Along a short reach of the Potomac River flood plain, Sigafoos (Art. 238) has found that trees having a shrubby form are generally flooded 5 times a year, trees about 4 inches in diameter are flooded once in 2 years, and larger trees are flooded less frequently. He concluded that the zonation in vegetation on flood plains is determined primarily by the magnitude and frequency of floods that are characteristic of a particular valley reach rather than by successional changes of vegetation through time.

Trees as indicators of glacial recession

In a study of the modern history of alpine glaciers on Mount Rainier, Wash., Sigafoos and Hendricks (1961) found that a moraine from which Nisqually Glacier started to recede about A.D. 1840 represents the maximum advance in at least the last 1,600 years. Moraines downvalley from two other glaciers also represent positions from which they started to recede at about the same time; however, other moraine remnants indicate that recessions from maximum advances occurred also about A.D. 1630 and 1740. Start of recession was determined by the maximum ages of trees growing on the moraines plus an interval between the start of recession and establishment of the trees.

Vegetation as an indicator of man's activities

F. R. Fosberg (1961a) has reported in a symposium on tropical vegetation that man's activities may have an important long-term influence on tropical vegetation that can be detected long after the abandonment of a human settlement. Indications of such influence in vegetation that otherwise appears normal include: displacement of altitudinal belts, dominance by single or few species, presence of exotic species, presence of unusual concentrations of economic plants, and anomalous habitat relations of communities and species. Large areas of savanna and of open forest, as well as rain forest with unusually well-developed undergrowth, are indications that suggest earlier human influence. This may often be verified by archaeological remains and abnormal soil profiles.

Vegetation patterns as indicators of past climates

Fosberg (Art. 365) has noted that in certain mangrove areas along the coast of southern Ecuador and central Queensland, distinctive bare areas exist between the mangrove and the coast itself. This pattern is believed to correlate with seasonally dry climate and resulting high salinity, and a large intertidal range.

The influence of vegetation on the shape of stream channels is summarized under the heading, "Morphology of stream channels," page A–62.

GLACIOLOGY AND GLACIAL GEOLOGY

A large part of the United States is covered by deposits formed by glaciers during Pleistocene time. These deposits determine the local topography and soil, and provide local aquifers. The study of glaciers and glacial deposits is, therefore, important to the understanding of the geology of many areas. A few recent findings of general interest in the fields of glaciology and glacial geology are summarized below. Other findings of local interest are summarized on pages A–11, A–12, A–13, A–18, A–24, A–36, A–43, A–53, A–63 to A–64, A–68, and A–87.

Studies of existing glaciers

A census of glaciers in the conterminous United States by M. F. Meier has revealed about 1,000 glaciers covering about 198 square miles. Seventy-seven percent of the glacier-covered area is in Washington and 9 percent is in Wyoming. An estimated 53,000,000 acre-feet of water stored as glacier ice in the mountains of the West annually contributes nearly 2,000,000 acre-feet of water to streamflow in the summer months.

Analysis of mass budget data from South Cascade glacier, Washington, by Meier (Art. 86) indicated a large deficiency during 1957–58 but approximate balance in 1958–60. Measurements by Arthur Johnson of the changes of thickness of Nisqually glacier, Washington, and Grinnell and Sperry glaciers in Montana indicated similar conditions. These studies suggest that the period of advancing and thickening glaciers in the Pacific Northwest has ended, at least temporarily.

According to a recently developed theory, kinematic waves initiated by climatic perturbations travel down a glacier and are the direct cause of advance or recession of the terminus. The first complete set of data on kinematic wave behavior in American glaciers was obtained by Johnson on Nisqually glacier. He showed that a wave traveled down the glacier at an average speed of more than 600 feet per year, several times faster than the speed of the ice. At one location, the ice velocity increased from less than 50 to more than 400 feet per year as the wave passed by.

Glacier hydrology

By comparing hydrologic data from basins of South Cascade and Grinnell glaciers with data from similar basins without glaciers, M. F. Meier and W. V. Tangborn (Art. 7) found that glacier runoff is not directly related to precipitation either in timing or amount. Glacier runoff possesses a marked diurnal fluctuation, is difficult to forecast because of the ever-changing characteristics of the snow and ice cover, and is regulated by natural changes in ice storage.

Glacial geology

During the course of recent work on the east coast of Greenland, J. H. Hartshorn has discovered evidence of widespread recent stagnation and retreat of glaciers on Milne Land, and in the valley of the Schuchert River north of Hall Fjord. A study of the history and mode of stagnation and of related glaciofluvial features in this area of modern glacial activity will aid in interpreting the history of glacial processes and deposits in places like New England, which have long been free of glaciers. Exploration of Pearyland, North Greenland, by W. E. Davies and D. B. Krinsley supports Lauge Koch's original observation of the local nature of Pearyland glaciation and of the absence of evidence for continental glaciation during Pleistocene time.

In the Boston area C. A. Kaye (Art. 34) has found evidence of 5 ice advances and 3 marine transgressions. The oldest glacial drift, recognized in Boston only in borings but exposed on Martha's Vineyard, is probably of Nebraskan or Kansan age. The successive deposits are of Illinoian, early Wisconsin (Iowan), middle

Wisconsin, and late Wisconsin (Cary) age. The youngest drift was deposited 13,000 to 14,000 years ago. The clays deposited during the marine invasions have been overridden by ice one or more times, yet are only moderately compacted. (See also p. A–12.)

On the east slope of Rocky Mountain National Park, work by G. M. Richmond shows evidence of at least three separate Pleistocene glaciations, which can be correlated with the Buffalo, Bull Lake, and Pinedale glaciations of Wyoming. Two minor advances of the ice have occurred since Pinedale time and have left moraines in the cirque heads. The Pliocene to Recent history of the Leadville district and the upper Arkansas Valley of Colorado has been studied by Ogden Tweto. Deposition of Pliocene alluvial-fan materials was followed by extensive valley cutting, icecap glaciation, additional valley cutting, filling of these valleys by coarse gravels, pedimentation, and finally valley cutting alternating with eight glacial advances.

From data on Recent and Pleistocene glaciers in Alaska, T. N. V. Karlstrom has detected evidence of a harmonic or near-harmonic system of paleoclimatic cycles. He suggests that the complex climatic record indicates the superposition of multiples of a 3,400-year glacier substage cycle, and that there is a genetic relation between theoretically derived astronomic oscillations and independently dated paleoclimatic sequences.

OCEANOGRAPHY AND MARINE GEOLOGY

In the rapidly expanding and potentially fruitful field of oceanography and marine geology, the fiscal year 1961 witnessed increased Geological Survey effort in collaboration with the Navy Hydrographic Office, the Coast and Geodetic Survey and private oceanographic institutions. Some of the results of this work are summarized below.

Oceanic crustal structure

H. S. Ladd, J. I. Tracey, Jr., and others have been active in planning and conducting test drilling and in studying materials from the "Mohole project" of the National Academy of Sciences, the ultimate objective of which is to obtain a sequence of samples and measurements through crustal rocks and sediments to the Mohorovičič discontinuity. In preliminary tests off the coast of Lower California a hole 600 feet deep was drilled in water 11,700 feet deep. The well penetrated a sequence about 550 feet thick consisting of sedimentary oozes mainly of Miocene age, and bottomed in an augite olivene pillow basalt of undetermined thickness.

Ecologic, zoogeographic, and paleontologic results

Analysis by Ruth Todd of Foraminifera from a Lamont deep-sea core off Walfisch Ridge in the eastern South Atlantic reveals an assemblage, mainly planktonic, of latest Cretaceous (Maestrichtian) age, comparable to one from a well along the south shore of Long Island.

Study by Patsy J. Smith of benthonic Foraminifera from cores off El Salvador collected by her on a Scripps Institution cruise reveals variation with depth in many species. Some arenaceous species reflect the grain size of the sediment in which they were found, others do not. Among calcareous species showing variation, the deeper water forms tend to be more highly ornate, with wider keels, carinae and costae.

J. C. Hathaway in cooperation with J. A. Ballard of the U.S. Navy Hydrographic Office found that unusual engineering properties in some sea bottom samples from the Atlantic Ocean are caused by the occurrence of the skeletal remains of diatoms and coccoliths in the sediments. These highly porous organisms have a high water content per unit weight of the sediments and apparently greatly reduce the cohesiveness of the material. The clay minerals in the sediments show only secondary effects on their physical properties. Probable properties can quickly be predicted by electron microscope examination of sediment samples for concentration of skeletal remains.

Work by P. E. Cloud, Jr., Z. S. Altschuler, and Helen Worthing on samples obtained from Caribbean waters by the Coast and Geodetic Survey has resulted in the clear differentiation of organic oozes formed beneath actively flowing and less active water masses, and the presence of phosphate-enriched limestone at a depth of 150 or more fathoms south from the Bay of Florida.

PERMAFROST STUDIES

Studies of permafrost continued during the past year in Alaska and Greenland. The work in Alaska was done in cooperation with the Atomic Energy Commission, the Office of Naval Research, the Corps of Engineers, U.S. Army, and the U.S. Air Force. The work in Greenland was done in cooperation with the Air Force Cambridge Research Laboratories. In addition to the studies summarized below, the geomorphology of permafrost is discussed on page A–61, and frozen ground as it affects highway construction in Alaska on page A–88.

Thermal studies

Analysis of temperature measurements to a depth of 1,200 feet at the Chariot test site in northwest Alaska by A. H. Lachenbruch, G. W. Greene and B. V. Marshall (*in* Kachadoorian and others, 1960, 1961) reveals that the present earth temperatures at depth are the product of an ancient period of colder weather and an ancient lower shoreline position. The mean annual surface temperature has increased a total of about 2° C, corresponding to a net annual accumulation of heat by the earth's surface of about 50 calories/yr/cm^2 over the last 6 or 8 decades. If the present climate persists, it will result in a reduction of inland permafrost thickness from its present value of about 1,170 feet to about 850 feet. Similar effects have been observed at Point Barrow by Lachenbruch and Brewer.[22] Earth temperature anomalies near the shoreline indicate a rapid encroachment of the Chukchi Sea in the last few thousand years. This implies that permafrost probably extends beneath the margin of the sea.

Preliminary calculations indicate that heat flow from the earth's interior is slightly over 10^{-6} cal/cm^{-2}/sec^{-1}. This is close to the worldwide average, and is contrary to the speculations of some that heat flow is anomalously large in the Arctic.

Areal distribution of permafrost

Studies in cooperation with the Air Force Cambridge Research Laboratories were continued in North Greenland at Centrum Sø by Daniel B. Krinsley (Art. 228). The upper surface of frozen ground in a beach terrace at the west end of the lake was 18 to 21.5 inches below the land surface on May 19, 1960, and by June 30 it had dropped to 22.5 inches. For two days only, July 11 and 12, the frost table dropped to 36 inches and then rose to about 32 inches where it stayed throughout the remainder of July. The frost table was 10 to 15 inches lower near the terrace banks, and ice wedges were visible where the river undercut the terrace.

The frost table caused impoundment of numerous small ponds at the west end of the terrace. Polygonal patterns in the sandy gravel of the terrace were mostly 20 to 24 feet on a side. Active polygon ridges were 2 to 4 inches high.

Large masses of foliated ground ice in the Galena area on the lower Yukon River in Alaska have been mapped and analyzed by Troy L. Péwé. The ice masses are less than 8,000 years old and have originated in thermal contraction cracks, a process described by Leffingwell.[23]

Permafrost has been reported by W. G. Pierce (Art. 65) in a peat deposit near Sawtooth Mountain, Wyo., in the southeastern part of the Beartooth Mountains. The presence of thaw depressions, similar in origin to the cave-in lakes or thaw lakes in permafrost terrain elsewhere, suggests that the Wyoming permafrost was formed many years ago.

Ground water in permafrost

In studies made for the United States Air Force, A. J. Feulner has located perennial, or near-perennial, sources of ground water for remote radar stations in Alaska in the shallow alluvium of seasonal mountain streams between the seasonal frost layer and the top of permafrost or bedrock.

Periodic observations on cold springs in northwestern Alaska by R. M. Waller (*in* Kachadoorian and others, 1960, 1961) show that: (a) springs occur in this region where permafrost is more than 1,000 feet thick, (b) these springs have a source of recharge, probably from a major river at some distance, (c) the ground water is under hydrostatic pressure causing the spring discharge to fluctuate with diurnal tides and atmospheric pressure, and (d) a complicated hydrologic regimen for the potable ground water may be inferred from its variable mineral content.

In the Fairbanks, Alaska, area D. J. Cederstrom (1961a) reports that permafrost is discontinuous under the Chena and Tanana Valleys. Within the city, permafrost increases in thickness away from the Chena River, and beneath the southern edge of the city it is as much as 225 feet thick. Where permafrost is present, shallow ground water may be available above permafrost; where shallow ground water is not available or not potable, it is necessary to drill through permafrost to the underlying unfrozen alluvium in order to obtain water. Beneath the gentle hill slopes north of the city water occurs under artesian head in unfrozen ground below a capping of permafrost. The level at which water stands in wells drilled on these slopes is probably determined by the altitude to which the permafrost cover rises uphill. Although drilling through permafrost is easier than drilling in unfrozen ground, wells passing through permafrost may freeze if not pumped regularly. (See p. A-44.)

A test well drilled by the Geological Survey at Kotzebue on the Chukchi Sea Coast of western Alaska, encountered water between 79 and 86 feet within an otherwise perennially frozen section. This water has a higher salt content than sea water and may have been concentrated by a process of fractionation by freezing.

GEOPHYSICS

Some of the more important findings of the Geological Survey in the field of geophysics are described below under the headings theoretical and experimental geophysics, ad regional geophysics and major crustal

[22] Lachenbruch, A. H., and Brewer, M. C., 1959, Dissipation of the temperature effect of drilling a well in Arctic Alaska: U.S. Geol. Survey Bull. 1083–C, p. 73–109, figs. 29–35.

[23] Leffingwell, E. deK., 1919, The Canning River region, northern Alaska: U.S. Geol. Survey Prof. Paper 109, p. 205–243.

studies. Geophysicalwork as it relates directly to other fields of geologic and hydrologic research is described under other headings as follows: permafrost, pages A–65 to A–66; thermoluminescence as applied to impact studies, page A–58; construction and engineering problems, page A–88; and the section on regional geology and hydrology, particularly pages A–13, A–16, A–19 to A–20, A–22, A–24, A–25 to A–26, A–30 to A–31, A–36, A–38, and A–43.

THEORETICAL AND EXPERIMENTAL GEOPHYSICS

Paleomagnetism

Since publication of their comprehensive review of published paleomagnetic data, A. V. Cox and R. R. Doell[24] have made further studies (1961) which indicate that the earth's radius during Permian times was the same as at present, within a measurement error of about 4 percent. They have also concluded that the "last" reversal horizon, found in Iceland, France, Japan, Russia, New Zealand, and Idaho, is almost certainly due to a reversal of the earth's magnetic field; thus, this reversal horizon (and perhaps a few preceding it) should become a very sharp worldwide marker horizon. The reversal occurred sometime during the late Pliocene to early Pleistocene.

Magnetic properties of rocks

Preliminary studies by Cox and Doell of demagnetization processes have shown that rocks may possess an extremely stable component of remanent magnetization—one that is not altered by magnetic fields of 3,000 oersteds.

Cox (1960a) has concluded that certain zones of anomalous remanent magnetization in basalts are caused by lightning, and that individual cells of highly-magnetized rock, due to a single lightning discharge, probably have dimensions on the order of 20 to 100 feet. From a detailed study of one such cell in a basalt in the Snake River Plain of Idaho, he concluded that the cell was caused by the intense magnetic field accompanying a lightning discharge with a peak current of 22,000 amperes.

A dual-purpose instrument for the precise determination of remanent magnetization and magnetic susceptibility of rock samples is described by L. A. Anderson (Art. 282).

Measurements of temperature in uranium ore bodies

In analyzing temperature data from a group of drill holes in uranium ore bodies near Grants and Laguna, N. Mex., P. E. Byerly has concluded that anomalies resulting from differences in rock properties are largely obscured by movement of natural and drilling water through the rocks, and that only in rather special cases would radiogenic ore bodies be detectable by temperature measurements in shallow drill holes.

Stress waves in solids

L. Peselnick and W. F. Outerbridge (1961) have investigated the modulus of rigidity, and the internal friction in shear of dry Solenhofen limestone by its response to stress waves ranging in frequency from 4 to 10^7 cycles per second at room temperature. This is the first time such measurements have been made on a single medium over such a wide frequency range. They found: (a) The modulus of rigidity is constant over the total frequency range for samples of the same density. (b) The internal friction in shear is lower by a factor of 5 in the cycle-per-second frequency range than in the megacycle frequency range. In the infrasonic frequency range, the internal friction in shear increases by 18 percent with the application of a 7.2-kg-per-cm^2 static axial tensile stress, but no large change in the internal friction occurs for axial compressive stresses of the same magnitude. (c) The internal friction in shear is strain-dependent, even for strains as small as 10^{-6} that are induced by a static axial tensile stress superposed on the dynamic torsional stress.

In addition to their significance in theoretical geophysics, these results are important in seismic exploration because most laboratory velocity measurements of rocks are made using either the resonance method or the pulse-echo technique, which use frequencies much greater than the frequencies used in seismic exploration. The results justify the use of high-frequency elastic data in seismic applications—at least for homogeneous and well-compacted rocks.

L. Peselnick and R. Meister (1961) have investigated a second-order phase transformation in polycrystalline chromium using ultrasonic techniques. The measurements were made at frequencies of 5 to 35 megacycles per second in the temperature range $-65°$ C to $+60°$ C. Anomalies in attenuation and velocity for the dilatational wave were found at $-19°$ C. The compressibility and Poisson's ratio were calculated, and from these quantities the anomalous specific heat was determined. The value of specific heat thus obtained agrees well with the calorimetric determination by Beaumont and others[25] of the specific heat anomaly, indicating that the anomaly in the specific heat is associated with the structural process. A dispersion in the dilatational velocity was found at $-19°$ C, and on the basis of a single relaxation process the limiting high-frequency velocity and relaxation time were estimated. From

[24] Cox, Allan, and Doell, R. R., 1960, Review of paleomagnetism: Geol. Soc. America Bull., v. 71, p. 645–768.

[25] Beaumont, R. H., Chihara, H., and Morrison, J. A., 1960, An anomaly in the heat capacity of chromium at 38.5° C.: Philos. Mag. v. 5, no. 50, p. 188–191.

these calculations a prediction of the magnitude of the attenuation was made, and this agreed within a factor of two with the measured attenuation.

By use of a seismic technique, R. E. Warrick (Art. 102) has measured Poisson's ratio for rock salt and potash ore of the Salado formation in New Mexico. Measurements in the laboratory using an ultrasonic pulse method (Peselnick and Outerbridge, 1961) agreed closely with in-place measurements. Uniaxial compression tests of the ore gave low values at low pressures, but with increase of pressure the values approached those obtained from the in-place measurements.

Electrical investigations

During recent years equipment has been developed for drill-hole logging of resistivity, guard conductivity, self-potential, induced polarization, and magnetic susceptibility. Field tests of this equipment have been conducted in drill holes penetrating various types of rock and have shown that some rock types and ores can be distinguished more precisely by logging more than one electrical property than by logging a single property. For example, C. J. Zablocki (Art. 241) found that the combination of low resistivity and high magnetic susceptibility in zones of the Duluth gabbro of Minnesota indicated the presence of significant sulfide mineralization, but that neither characteristic was sufficient by itself. Sometimes the measurement of a single property is adequate, as in the Portage Lake lava series of Michigan, where G. V. Keller (Art. 389) found that the lower resistivity of amygdaloidal upper parts of flows distinguished them from nonamygdaloidal parts of the flows.

Irwin Roman (1960) has compiled a comprehensive volume of formulas, curves, and tables for the interpretation of resistivity surveys on a single overburden earth in which the contacts are horizontal and the two media are both homogeneous and isotropic.

Glacial ice of the Athabasca Glacier, Alberta, Canada, was studied by electrical methods by G. V. Keller and F. C. Frischknecht (1960). The resistivity method was useful for determining the thickness and layering of the ice; the electromagnetic method was somewhat superior for determining the thickness of the ice and the nature of the underlying material.

F. C. Frischknecht and E. B. Ekren have applied electromagnetic methods to tracing a taconite iron-formation on the Gogebic range. The chief advantage of electromagnetic methods over conventional magnetic methods is that they are not influenced by remanent magnetization. Experimental electromagnetic measurements also show promise as a means of estimating the magnetic susceptibility and magnetite content of potential taconite ore bodies.

Induced polarization in rocks

Invesigations of induced polarization in rocks have included both laboratory studies of the phenomena causing induced polarization, and measurements of induced polarization in rock cores and in drill holes. L. A. Anderson (Art. 416) has determined the dependence of the overvoltage of a single pyrite crystal on the amount of current passing through one of its surfaces and has found significant deviations from the behavior reported for metallic electrodes.

G. V. Keller (1960) has described experiments to determine the mechanism of induced polarization in rocks not containing the metallic minerals necessary for the creation of overvoltage. His results, which support an earlier paper of Keller and Licastro,[26] may be summarized as follows: negatively-charged clay particles at pore constrictions in a rock prevent the flow of anions through the constriction, causing them to pile up near the constriction while they are under the influence of the electrical pulse; when the pulse is interrupted, the anions diffuse away from the pileups and create the observed electrical transient.

Induced polarization has been measured in drill holes as a part of several field investigations. In Keller's study of the electrical properties of Precambrian traps (Art. 389), the induced polarization response was the same for the amygdaloidal and the non-amygdaloidal parts of the traps when determined in the drill holes. Zablocki found a maximum response in gabbro (Art. 241) when it contained a few percent of sulfides; the increase of conductivity attending greater concentrations of sulfides diminished the response.

Seismic-electric effect

It has been known for many years that electrical signals accompany seismic waves propagated by earthquakes and large underground explosions. The electrical signals due to some underground nuclear and chemical explosions at the Nevada Test Site have been measured by C. J. Zablocki and G. V. Keller (Art. 395). They observed greater voltages along radii from the explosion sites than transverse to the radii. The first voltages appeared at about the same time as the first seismic energy.

Electronic computer applications

Use of electronic computers in processing and interpreting geophysical data has increased greatly in recent years.

A comprehensive system for analyzing gravity and magnetic fields on digital computers, prepared by R. G.

[26] Keller, G. V., and Licastro, P. H., 1959, Dielectric constant and electrical resistivity of natural state cores: U.S. Geol. Survey Bull. 1052-H, p. 257-285.

Henderson,[27] has been used extensively within and outside the Survey. Comparative studies by L. L. Nettleton and John Cannon show that Henderson's system is consistently more accurate than others tested for use in determining the errors developed in airborne gravity measurements.

Regional effects on contoured geophysical maps are being separated from local effects by a surface-trend analysis computer program, which fits least-squares polynomial surfaces of various order to the observed data. Initiated by G. D. Bath, who did linear surface-trend analyses on a desk calculator, the process has been extended in the computer program to third-order polynomials.

Seismic surface wave dispersion methods are an effective means for studying the structure of the earth's crust. R. G. Henderson and G. V. Keller have initiated computer-oriented studies of Rayleigh and Love wave dispersion in multilayered media. The Haskell-Thomson matrix formulation of the period equation was used by David Handwerker to write a program that computes phase and group velocities of surface waves for given values of wave number or the period for prescribed layered velocity and density configurations. Calculations of this kind have been used by S. W. Stewart to test various crustal models.

The frequency content of seismograms is being investigated by means of three new aids: (a) a semi-automatic device for digitizing seismograms, (b) a computer program that gives the Fourier amplitude and phase spectra, and (c) a new method of machine contouring. Some of these procedures have been used in the comparison of seismograms from nuclear explosions and aftershocks (Stewart and Diment, Art. 103) and in determining the frequency content of initial refraction waves (Diment, Stewart, and Roller, 1961).

F. C. Frischknecht and James Marsheck have used the Datatron computer to evaluate the basic integrals given by Wait [28] for the fields of an oscillating dipole over a two-layer ground. The results facilitate use of electromagnetic surveys—particularly airborne surveys—to determine the "background" electromagnetic response of overburden and country rock near ore bodies and to map gently-dipping rock strata.

Geophysical abstracts

Geophysical Abstracts, a quarterly publication of the Geological Survey, is now in its thirty-third year (Clarke and others, 1960 a, b, c, and 1961 a, b). In 1961, articles abstracted from more than 450 journals in 20 languages increased by more than a third over the number published in 1960. The staff and volunteer abstracters cover literature pertaining to physics of the solid earth, application of physical methods and techniques to geologic problems, and geophysical exploration.

[27] Henderson, R. G., 1960, A comprehensive system of automatic computation in magnetic and gravity interpretation: Geophysics, v. 25, no. 3, p. 569–585.

[28] Wait, J. R., 1958, Induction by an oscillating magnetic dipole over a two-layer earth: Appl. Sci. Research, sec. B, v. 7, p. 73–80.

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REGIONAL GEOPHYSICS AND MAJOR CRUSTAL STUDIES

Alaska

Gravity data obtained in the Tanana Valley by D. F. Barnes (Art. 383), show a 40 milligal low at Minto Flats, which suggests a thick sequence of rocks of Tertiary and Quaternary ages. (See p. A–42.)

Pacific Coast

L. C. Pakiser (1960) has described a large gravity low in the Lassen Volcanic National Park, Calif., region of the southern Cascade Range. This is an area of predominantly mafic to intermediate rocks, but it also includes a significant amount of silicic rocks. The mass deficiency of the gravity low was found by application of Gauss's theorem to be 3×10^{18} g, which corresponds to a volume of 3,700 mi^3 of material 0.2 g per cm^3 less dense than the enclosing rocks. This mass deficiency is equivalent to a square prismatic load of material of density 2.67 g per cm^3, 100 km on a side, and 1 km high. This is approximately the load of the southern Cascades in the Lassen region, so the Cascades are in approximate isostatic equilibrium. The mass deficiency may be caused by a gigantic volcano-tectonic depression filled with low-density volcanic rocks, a mass of low-density crustal rocks such as a silicic batholith, or a combination of the two. As determined by the gravity data, the upper surface of the mass deficiency is no more than 10 km deep.

In Washington, west of the Cascade Range, D. J. Stuart (Art. 248) has found that pronounced gravity highs correlate with exposures of Eocene volcanic rocks of mafic composition. The dense crustal rocks of which these gravity highs are the expression must extend to depths of tens of thousands of feet below sea level.

Sierra Nevada

Isostatic reductions of a closely spaced profile of gravity stations across the southern Sierra Nevada, Calif. by H. W. Oliver, decrease the Bouguer anomaly by 80 to 90 percent, adding considerable support to the theory of isostasy. Calculations using observed gravity gradients and a large number of density measurements of rock samples show that a least part of the isostatic compensation results from a lateral easterly decrease in the density of rocks within the earth's crust rather than entirely by a mountain root of crustal material protruding down into the earth's mantle, as envisioned by Airy.

A large gravity low in Long Valley, Calif., has been interpreted by L. C. Pakiser (Art. 106) as the expression of a volcano-tectonic depression. This low is the expression of a mass deficiency of 7.8×10^{17} g, which corresponds to a volume of 470 mi^3 of material 0.4 g per cm^3 less dense than the surrounding material.

A geophysical study of southern Owens Valley, Calif., by M. F. Kane and L. C. Pakiser (1961) indicates that the deepest parts of the bedrock floor range from 3,000 to 9,000 feet below the surface. Steep gravity gradients outline a series of steeply dipping faults along the boundaries of the valley. A sharp velocity boundary within the valley sediments suggests a change in the rate of deposition, which was probably caused by renewed uplift of the nearby mountain masses.

Interpretation of a gravity low at Sierra Valley, Calif., by W. H. Jackson, F. R. Shawe, and L. C. Pakiser (Art. 107) suggests that the valley is bounded by steeply dipping faults, and in its deepest part is filled with a minimum of 2,500 to 3,000 feet of Cenozoic deposits.

D. R. Mabey (Art. 249) reports the discovery of a large intrusive body north of Darwin, Calif., based on aeromagnetic evidence. Along the east side of the magnetic anomaly is a gravity high that apparently is produced by dense sedimentary rocks that were altered by the intrusive mass.

Basin and Range

Regional gravity data in Nevada analyzed by D. R. Mabey, L. C. Pakiser, and M. F. Kane (1960) show an inverse relation to topographic features that are 100 miles or more in width, implying some form of isostatic compensation. Studies by M. F. Kane and J. E. Carlson (Art. 390) in Clark County, Nev., and by Mabey in Nevada and eastern California indicate that in some places the deficiencies are caused by old masses produced by geologic processes. Mabey believes that some of the larger mountain masses are completely compensated. Kane believes that tilting of large crustal blocks may play an important part in the isostatic adjustment of near-surface mass deficiencies.

Electromagnetic measurements made by F. C. Frischknecht and E. B. Ekren (Art. 385) over the Helmet fanglomerate of Tertiary age in the Twin Buttes quadrangle near Tucson, Ariz., show that although individual beds vary considerably in resistivity, the large-scale response is that of an electrically homogeneous medium. Local variations in resistivity and the low over-all resistivity of the Helmet fanglomerate severely limit the investigation of ore bodies at greater depth.

Large gravity and magnetic lows associated with the Rio Grande trough indicate to H. J. Joesting and others (Art. 392) that the trough is constricted near Albuquerque and that the greatest thickness of valley fill and the ancient course of the Rio Grande were west of the present river.

Rocky Mountains

A gravity low of large area was found in the Yellowstone Plateau, Wyoming, Idaho, and Montana by L. C. Pakiser and H. L. Baldwin, Jr., (Art. 104). The mass deficiency of this low is 5×10^{18} g, which corresponds to a volume of 4,000 mi^3 of material 0.3 g per cm^3 less dense than the surrounding material. The Yellowstone gravity low may represent a volcano-tectonic depression, a silicic batholith, a magma chamber, or some combination of these.

Major structural features in the southern Black Hills, Wyoming and South Dakota, have been delineated as part of a regional gravity survey by R. A. Black and J. C. Roller (Art. 243). Two intersecting steep gravity gradients correlate well with steep monoclinal folding along the western flank of the Black Hills.

Gravity data in the southern Rocky Mountains of Colorado indicate to D. J. Stuart and R. R. Wahl (Art. 245) that the mountains are isostatically compensated on a regional scale, but that local masses are not locally compensated. Comparison by Donald Plouff (Art. 244) of gravity data obtained in the Harold D. Roberts Tunnel near Dillon, Colo., and on the surface above the tunnel indicates that the density of near-surface crustal rocks ranges from 2.61 to 2.81 g per cm^3. Samples from an area nearby had measured densities in a narrower range. The larger range of apparent densities determined from gravity is considered to be the result in part of anomalously low vertical gravity gradients associated with the mass deficiency that compensates the Rocky Mountains.

Analysis by G. E. Andreasen and M. F. Kane (Art. 391) of gravity data in the southern Sangre de Cristo Mountains, N. Mex., indicates that the mountain mass is at least partially compensated.

Seismic studies

A new all-transistorized seismic-refraction recording system for crustal studies has been designed and built by Dresser Electronics, S. I. E. Division, to meet the Geological Survey's performance specifications. The new system has flat frequency response within 3 db from 1 to 200 cps or higher, a dynamic range of 60 db, high gain, extremely low noise, selective high- and low-cut filtering, and oscillographic and magnetic-tape recording with playback. Six of the new seismic systems have been placed in operation in eastern Colorado. A radio-communications system for long-offset seismic-refraction profiles in crustal studies is under development by G. B. Mangan and J. Clark. The system combines low-frequency (180-kc) transmission from the shot points, multi-frequency transmitters and receivers in a higher frequency range at shot points and recording locations, and a master communications vehicle equipped with 500-watt transmitters at the higher frequencies (3237, 5287.5, and 7880 kc).

Pending delivery of the new recording equipment, conventional exploration-type reflection- and refraction-seismic equipment has been used to record high-explosives shots at the Nevada Test Site and near Rifle, Colo. Recordings of the shots at the Nevada Test Site have been made along a line toward Mono Lake, Calif. Earlier, a seismic-refraction profile from nuclear shots at the Nevada Test Site was recorded between the Nevada Test Site and Kingman, Ariz., by W. H. Diment, S. W. Stewart and J. C. Roller (1961). The thicknesses and velocities of crustal layers obtained on interpretation of the traveltime data from this profile were: $H_0=1.7$ km, $V_0=5.2$ km per sec; $H_1=26.7$ km, $V_1=6.15$ km per sec; $H_0+H_1\cong 28$ km, $V_2=7.81$ km per sec.

R. E. Warrick has analyzed results of recordings from a 1,000-pound high-explosives shot in a drill hole in shale at the experimental mine of the U.S. Bureau of Mines at Anvil Point, near Rifle, Colo. First-arriving energy was recorded at 1.2, 66.5, and 152 km with an apparent velocity of 6.3 km per sec. On the basis of detection of these arrivals superimposed on strong background noise, it was concluded that detectable first arrivals at 200 km could be obtained from a well-tamped 2,000-pound high-explosives shot in similar rock. Thus, seismic-refraction exploration of the crust using relatively small charges need not be restricted to shooting in bodies of water.

R. B. Hofmann (Art. 246) has found that energy released by aftershocks of the Hebgen Lake, Mont., earthquake of 1959 has semidiurnal periodicity. S. W. Stewart and W. H. Diment (Art. 103) have studied changing frequency content as a function of time for earthquake aftershocks and nuclear shots. Such studies, using calculations of Fourier transforms by digital-computer methods, may be useful in determining dispersion of seismic surface waves and identifying events after the first arrivals on a seismogram, such as reflections in the presence of strong background noise.

Other studies

M. F. Kane (Art. 242) has shown that detailed gravity measurements may be used to determine the approximate size and shape of many outcropping or near surface igneous intrusives and that the application of gravity surveys should be useful in geologic studies of plutons and areas containing igneous outcrops.

Using a similar approach, J. W. Allingham (Art. 387) has computed the relative width of zones of magnetic rock and the approximate attitude of intrusive contacts in northern Maine by a three-dimensional analysis of aeromagnetic anomalies.

Computations for the magnetic fields of prismatic models with infinite thickness and for any magnetic polarization have been started. Analysis of these data by Isidore Zietz (1961) has led to an empirical rule which, when applied to aeromagnetic data, permits the rapid calculation of the in-place direction of the magnetic vector. This simplified procedure will permit determination of the in-place direction of the remanent magnetization vector in some volcanic areas without the time-consuming need for collection and measurement of rock samples.

Effects of fluid withdrawal

Land subsidence caused by the withdrawal of underground fluids is occurring in many areas in the United States and in other countries. Studies of the principles controlling the compaction (deformation) of reservoir systems due to the change in grain-to-grain load caused by fluid withdrawals were begun in the San Joaquin Valley, Calif., in 1956. These studies have been extended to obtain information on subsidence from the same cause in many parts of the world. Notable examples are subsidences of oil fields at Wilmington, Calif., and in the Lake Maracaibo Basin, Venezuela, of gas fields at Niigata, Japan, and in the Po River Valley, Italy, and of artesian aquifer systems in Mexico, Japan, and in Texas and California in the United States.

In the subsiding areas in the San Joaquin Valley, Calif., compaction of aquifer systems in unconsolidated sediments is being measured directly and continuously by means of subsurface bench marks installed at several depths and by compaction recorders at the land surface. Measured compaction has been shown by B. E. Lofgren (Art. 24) to be directly related to changes in artesian head and to be approximately equal to land subsidence as measured by repeated leveling. As defined by bench marks at several depths the compaction is occurring almost wholly in the confined aquifer system.

Using consolidation tests of core samples from an aquifer system, historic artesian-pressure decline data, and well-log data, R. E. Miller (Art. 26) has shown that compaction computed in accord with Terzaghi's theory of consolidation agrees closely with subsidence measured at surface bench marks.

In laboratory studies of the compaction of fine-grained montmorillonite-rich clayey sediments, R. H. Meade (Art. 116) has developed a numerical index of preferred orientation as a refinement of X-ray diffractometer methods for study of clay-mineral petrofabrics. During the course of his studies Meade (Art. 324) found that, under compacting pressures up to 60 kg/cm^2 (900 psi), montmorillonite does not develop preferred orientation, in contrast to behavior of other clay minerals of platy habit.

S. W. Lohman (Art. 23) has developed an equation for computing the amount of elastic compression of aquifers caused by removal of ground water. J. F. Poland (Art. 25) has applied this equation to studies of compaction and subsidence in the Los Banos-Kettleman City area, California. He has concluded that for highly compressible and heavily pumped artesian systems, demonstrated to have ratios of subsidence to artesian-head decline of 1/10 to 1/25, the stored water released over a period of years by compaction of fine-grained clayey beds may be 50 times as great as the storage released by elastic expansion of the water and elastic compression of the aquifer system.

At the Wilmington oil field, in Long Beach, Calif., compaction of the oil reservoir system had caused 26 feet of subsidence by 1960. Repressuring of the oil zones by injecting saline ground water was begun on a large scale by local agencies in 1958, to control subsidence and to increase oil recovery. Subsidence was stopped near some injection wells within 3 months after injection began (Poland, 1960a). Results of the injection program to date suggest that subsidence can be controlled effectively by repressuring.

Sensitive liquid-level tiltmeters described by F. S. Riley (Art. 136) are being used to detect the minute subsidence of the land surface that occurs around a pumped artesian well. When correlated with the artesian-head change in the aquifer during pumping, these tests provide data for computing the coefficient of storage and the modulus of elasticity of the aquifer system directly from the aquifer deformation. Results to date indicate differential subsidence on the order of 10 to 100 microns between stations about 5 and 50 meters, respectively, from the pumped well.

GEOCHEMISTRY AND MINERALOGY

The broad field of geochemistry, mineralogy, and petrology is concerned with the determination of the chemical and physical properties of rocks and minerals, the description of new minerals, experiments and observations on the origin of ores, minerals and rocks, compilation of data on the occurrence and relative abundance of elements in rocks and ores, and experiments and observations on organic processes and materials. Some of the more important phases of this work are summarized below under three main headings: experimental geochemistry and mineralogy, field geochemistry and petrology, and organic geochemistry. Findings that are directly applicable to other research programs are summarized under other headings, such as, isotope and nuclear studies, page A-80; geochemical and botanical exploration, page A-95; radioactive waste disposal investigations, page A-94; resource investigations, page A-1; and regional investigations, page A-9.

EXPERIMENTAL GEOCHEMISTRY AND MINERALOGY

Mineralogical studies and description of new minerals

Several significant studies have been made in mineralogical chemistry. A new procedure for the synthesis of large single crystals of andersonite, $Na_2CaUO_2(CO_3)_3 \cdot 6H_2O$, developed by Robert Meyrowitz and Daphne Ross (Art. 113), has produced crystals up to 1 mm in average diameter suitable for crystal-structure investigation. E. D. Jackson (Art. 252) has produced an X-ray determinative curve for natural plagioclases of composition An_{30} to An_{85} calibrated against chemically analyzed samples. A critical review of chloritoid analyses by Margaret D. Foster (Art. 259) shows that recent analyses are in good agrement with the structure proposed by Brindley and Harrison.

A new heating stage for the X-ray diffractometer, developed by B. J. Skinner, David Stewart, and Joseph Morgenstern, has been used for measuring thermal expansions of minerals over a wide range of temperatures. The thermal expansions of a number of sulfide and selenide compounds have been measured up to their decomposition temperatures. The molar volumes of the aluminosilicates kyanite, andalusite, and sillimanite were measured up to 1,050°C for the first time. For kyanite, which is triclinic, thermodynamic calculations made by S. P. Clark, Jr., B. J. Skinner, and D. E. Appleman (1960) required use of a digital computer to reduce the raw measurements.

A. O. Shepard (Art. 264) has shown that zeolites comprising up to 45 percent of tuffs of the Oak Spring formation, Nye County, Nev., are in part mixtures of clinoptilolite and a heulandite-type mineral. These two zeolites, which have virtually identical X-ray powder diffraction patterns at 25° C, can be distinguished by a phase change occurring in heulandite-type minerals at 250° to 350° C.

A new tantalum borate, $TaBO_4$, has been found by Mary E. Mrose in a specimen from Manjaka, Madagascar. The name behierite has been proposed for this mineral, which has a zircon-type structure and is identical with synthetic $TaBO_4$ as described by Zaslavskii and Zvinchuk.[29]

[29] Zaslavskii, A. I., and Zvinchuk, R. A., 1953, On the reaction of Ta_2O_5 with B_2O_3 and the structure of $TaBO_4$: Dokl. Akad. Nauk SSSR, v. 90, no. 5, p. 781–783.

In a study of merumite, a mixture of chromium oxides from British Guiana, Charles Milton, E. C. T. Chao, Mary E. Mrose, and Blanche Ingram have isolated and identified the phases Cr_2O_3, CrO_2, and $CrO(OH)$.

A new sodium calcium vanadyl vanadate, to be named grantsite, has been described by Alice Weeks, Marie Lindberg, and Robert Meyrowitz (Art. 125) from occurrences in New Mexico and Colorado.

The new hydrous strontium borate, tunellite, $SrO \cdot 3B_2O_3 \cdot 4H_2O$, has been described by R. C. Erd, Vincent Morgan, and Joan R. Clark (Art. 255) from occurrences in the Kramer borate district and in Death Valley, Calif. Tunellite is isostructural with nobleite, $CaO \cdot 3B_2O_3 \cdot 4H_2$.

Margaret D. Foster (1960a) has shown from structural formulas that the trioctahedral micas form a complete Mg-replacement series, from ideal phlogopite with complete octahedral occupancy by Mg, through the biotites, to siderophyllite and lepidomelane with essentially no Mg. A related study (Foster, 1960b) shows that lepidolites can be interpreted as if (a) derived from muscovite by replacement of some of the octahedral Al by Li or (b) derived from siderophyllite, through protolithionite and zinnwaldite, by replacement of Fe^{+2} by Li.

Foster has proposed a new quantitative classification of the chlorites based on: (a) replacement of Mg by Fe^{+2}, and (b) replacement of tetrahedral and octahedral Al by Si and Mg, respectively, in the structural formulas.

Charles Milton and Mary E. Mrose have found that pathologic lung deposits in the rare disease, pulmonary alveolar microlithiasis, consist essentially of carbonate apatite. Dorothy Carroll (Art. 400) has shown that micaceous laminae in Paleozoic sandstones from Florida consist of elongated flakes of $2M_1$ muscovite, chlorite and a degraded mica.

Crystal chemistry

Investigations of crystal chemistry and crystal structure are aimed at a better understanding of structural states and order-disorder phenomena in feldspars. Joan R. Clark and D. E. Appleman (1960a) have completed a study of the crystal structure of reedmergnerite, $NaBSi_3O_8$, the boron analog of albite. The boron-silicon distribution among the tetrahedral sites was found to be completely ordered. Charge balance calculated on the basis of a simple ionic model was found to give an inadequate picture of the stability of the feldspar structures.

D. R. Wones and D. E. Appleman (Art. 260) have reported on synthetic monoclinic iron-sanidine, $KFeSi_3O_8$, formed by the reaction of mica with gas in the system K_2O–SiO_2–Fe–O–H_2O.

D. E. Appleman and H. T. Evans, Jr., have collaborated with N. Morimoto (1960) of the Geophysical Laboratory, Carnegie Institution of Washington, in a crystal chemical study of the clinopyroxenes. Determination of the detailed structures of clinoenstatite and pigeonite showed the effect of the introduction of different cations into the single-chain diopside-type structure.

C. L. Christ and Joan R. Clark have continued their structural and crystal-chemical studies of hydrated borate minerals. Refinement of the crystal structure of the synthetic compound $CaB_3O_5(OH)$ has completed the investigation of the colemanite series, $2CaO \cdot 3B_2O_3 \cdot nH_2O$. (See Clark and Christ, 1960b.) Comparison of the bonding and configuration among all members of this series is currently in progress. Joan R. Clark and Mary E. Mrose (1960) have described an unusual relationship between the strontium borate minerals veatchite and *p*-veatchite. The discovery of single crystals of the ammonium borate larderellite, suitable for X-ray studies, has enabled Clark (1960) to complete the investigation of the ammonium pentaborate minerals. Crystal chemical considerations have led to the most probable structural formula $NH_4B_5O_8(OH)_4$ for larderellite.

Crystal-chemical studies of uranium minerals have continued with a detailed analysis of the crystallographic constants, symmetry, and structural relationships of the uranyl oxide hydrate minerals by C. L. Christ and John R. Clark (1960a). Malcom Ross and Howard T. Evans, Jr., (1960) have solved the crystal structure of cesium biuranyl trisulfate, furnishing the first detailed structural information on a uranyl sulfate compound.

The determination of the crystal structure of fairfieldite, triclinic $Ca_2(Mn,Fe)(PO_4)_2 \cdot 2H_2O$, was completed by Mary E. Mrose and D. E. Appleman (1960) as part of a continuing study of the crystal chemistry of phosphate minerals. The investigation confirmed a structural relationship between the triclinic and monoclinic members of the $A_2B(XO_4)_2 \cdot 2H_2O$ series of minerals, which includes phosphates, arsenates, and sulfates.

Several investigations have been carried out to determine accurate unit-cell dimensions and changes in cell dimensions with changing composition. Shirley Mosburg, Daphne R. Ross, Philip M. Bethke, and Priestley Toulmin 3d (Art. 273) have refined the cell dimensions of herzenbergite (SnS), teallite ($PbSnS_2$), and Sn_2S_3, as a preliminary step in an investigation of the phase relations in the system Pb–Sn–S. Bethke and Paul B. Barton, Jr., (Art. 114) have established the relationship between unit-cell edge and composition in PbS–

PbSe and ZnS–ZnSe solid solutions, cadmium-bearing galenas and $CuFeS_{1.90}$-$CuFeSe_{1.90}$ solid solutions. Studies on the H–Na exchange in montmorillonite by Alfred Pommer showed that change in interplanar spacing is related to replacement of H^+ by Na^+ ions in the interlayer positions.

Experimental geochemistry

Research is continuing on silicate systems of prime geologic importance. David B. Stewart has found that the lowest melting silicate-rich mixtures in the system $NaAlSi_3O_8$–$LiAlSiO_4$–SiO_2–H_2O at 2,000 bars correspond in composition to the large, poorly zoned spodumene and petalite pegmatites, which are a major world source of lithium. This supports the hypothesis that the pegmatites were formed by fractional crystallization of lithium-bearing granitic magma. W. C. Phinney and Stewart (Art. 413) have studied some physical properties of bikitaite, $LiAlSi_2O_6 \cdot H_2O$. Reversible dehydration and ion-exchange effects indicate that bikitaite is a zeolite. The dehydration curve shows characteristic breaks at 180° C and 280° C, corresponding to loss of ¼ and ¾ of the water; hydrothermal decomposition to petalite and eucryptite occurs at about 390° C in the range of 1 to 4 kilobars H_2O pressure. Results have been correlated with the crystal structure proposed by D. E. Appleman (1960).

Herbert R. Shaw has determined points on the four-phase curve (K-feldspar-quartz-liquid-gas) in the system $KAlSi_3O_8$–SiO_2–H_2O at 500, 1,000, 2,000, and 4,000 bars. Liquidus studies have been extended into the quaternary system $KAlSi_3O_8$–Al_2O_3–SiO_2–H_2O at 2,000 bars, and it was found that the liquidus is lowered 20° to 30° C with small additions of Al_2O_3. The results imply that about 3 percent muscovite could be produced from the minimum-melting composition in this system at 2,000 bars. Some muscovite granites have approximately this amount, but most muscovite-bearing pegmatites have considerably more muscovite in bulk composition, as for example, the Hugo pegmatite which has been described by J. J. Norton.[30]

The addition of MgO to the system $KAlSi_2O_8$–SiO_2–H_2O at 2,000 bars H_2O pressure was found by D. R. Wones to lower the minimum melting temperature from 765° C to 710° C, at which temperature phlogopite appears in addition to sanidine, quartz, melt, and gas. The composition at the minimum contains about 5 weight percent MgO. At 2,000 bars H_2O pressure, the assemblage sanidine–enstatite–gas is unstable and is represented by phlogopite–quartz–gas or phlogopite–melt–gas. The phlogopite–quartz–gas assemblage is stable to above 800° C at this pressure.

The optical properties and unit-cell dimensions of biotites on the join annite $[KFe_3AlSi_3O_{10}(OH)_2]$–phlogopite $[KMg_3AlSi_3O_{10}(OH)_2]$ and the join annite-siderophyllite $[KFe_2AlAl_2Si_2O_{10}(OH)_2]$ have been studied by D. R. Wones (1960); complete miscibility is indicated. Studies of phase equilibria at 1,000 and 2,000 bars gas pressure show that the annite molecule reacts with gas to form potassium feldspar, magnetite (hematite), and a magnesium- or aluminum-rich biotite at temperatures between 400° C and 800° C.

Studies by J. J. Hemley (Art. 408) of alteration reactions and hydrolysis equilibria in the system Na_2O–Al_2O_3–SiO_2–H_2O at elevated temperatures and pressures have outlined the stability relations among the phases albite, paragonite, montmorillonite, and kaolinite. The relationships are similar to those found by Hemley[31] for K-feldspar, muscovite, and kaolinite except that higher alkali:H^+ ratios are needed to crystallize paragonite and albite than are required for the corresponding potassium phases. The experimental findings are useful in the genetic interpretation of patterns of wall-rock alteration associated with certain ore deposits. Hemley has also examined the stability relations among analcite, montmorillonite and paragonite and has shown that, at low temperatures and in a silica-deficient environment, the alkali:H^+ ratio of the solutions is the principal control on the development of clay as against zeolite.

Continued investigation of the system SiO_2–H_2O by George Morey, R. O. Fournier, and Jack Rowe has shown that the solubility of quartz at 25° C is about 6 ppm (parts per million). The rate of equilibration as reported by Fournier (1960) is extremely slow, with extensive metastable solubility (as much as 80 to 400 ppm) occurring for more than 400 days before equilibration occurs.

Investigations of the chemical processes by which various types of sedimentary deposits are formed are in progress on several fronts. In the study of evaporite phase equilibria, E-an Zen has attempted to determine the saturation curves in the system $CaSO_4$–NaCl–H_2O by approaching equilibrium from both directions. He has found that anhydrite consistently converts to gypsum, even at 70° C, as much as 30° above the conversion temperature previously reported by MacDonald.[32] According to the newer data of Zen, the gypsum-anhydrite transition temperature at 1 atmosphere in the $CaSO_4$ binary is changed from 41° to 46° C.

[30] Norton, J. J., 1960, Hugo pegmatite, Keystone, South Dakota, *in* Short papers in the geological sciences: U.S. Geol. Survey Prof. Paper 400–B, p. B67–B70.

[31] Hemley, J. J., 1959, Some mineralogical equilibria in the system K_2O–Al_2O_3–SiO_2–H_2O: Am. Jour. Sci., v. 257, p. 241–270.

[32] MacDonald, G. J. F., 1953, Anhydrite-gypsum equilibrium relations: Am. Jour. Sci., v. 251, p. 884–898.

Furthermore, calorimetric uncertainties correspond to about ±25° for the transition temperature, thus encompassing all of the conflicting experimental data, including those of van't Hoff and others.[33]

Recent work by Robert O. Fournier (Art. 403) shows that evaporite beds in the Salado formation of Permian age in Eddy County, N. Mex., contain widespread regular interlayered chlorite-vermiculite. The 28A basal unit expands to 31A upon glycolation and contracts to 24A upon prolonged heating at any temperature between 120° and 500°C.

Many studies on geochemical aspects of the origin and emplacement of ore bodies are in progress. In attempting to explain some steep thermal gradients that existed during ore formation in the Central City district, Colorado, Paul Barton, Priestley Toulmin 3d, and Paul Sims (Art. 412) have shown that the ore-forming fluid may cool by several processes other than the commonly accepted one of heat exchange with the wallrock, and that the probable major heat dissipating processes at Central City were first the movement of high pressure, high-temperature magmatic solutions into a low-pressure environment followed closely by the mixing of the solutions with circulating ground waters.

Paul Barton and Priestley Toulmin 3d have calibrated the electrum-tarnish method for measuring the activity of sulfur, a_{S_2}, in laboratory experiments and have determined a number of univariant a_{S_2} versus temperature curves for geologically important reactions, the most important of which is the breakdown of pyrite to pyrrhotite and sulfur vapor. The a_{S_2} versus temperature curve for this reaction is now known from 743° to 300° C and a large, heretofore unknown, bending of the curve reduces the stability field of pyrite very appreciably at lower temperatures and indicates that stability diagrams calculated for sedimentary environments may require extensive revision. The electrum-tarnish procedure has also been employed to define quantitatively the variation of the composition of pyrrhotite (Fe : S ratio) with temperature and, a_{S_2}, thus making possible the use of pyrrhotite itself as an instrument for the measuring of a_{S_2}.

As part of a study of the system CoS–FeS–ZnS, W. E. Hall (Art. 115) has determined that the unit-cell edge of ternary sphalerites follows the equation: $A=5.4093+0.000456X-0.000700Y$, where A is in angstroms, X is mol percent FeS, and Y is mol percent CoS. A maximum of about 33 mol percent CoS can be held in solid solution in iron-free sphalerite at 850° C.

[33] van't Hoff, J. H., Armstrong, E. F., Hinrichsen, W., Weigert, F., and Just, G., 1903, Gips und anhydrite: Zeitschr. physik. Chemie, v. 45, p. 257.

B. J. Skinner (1960) has shown that luzonite (CU_3AsS_4) is the low-temperature polymorph of enargite. The inversion temperature is at about 300° C, a factor of some importance in estimating the temperatures of formation of certain ore deposits. An asymmetric solvus exists between enargite (Cu_3AsS_4) and famatinite (Cu_3SbS_4), and preliminary studies indicate that this relation will make the natural assemblage, enargite plus famatinite, a useful geothermometer.

Eugene Roseboom (1960) has made an intensive study of the Cu–S system, making extensive use of high-temperature X-ray diffraction techniques. Digenite, approximately Cu_9S_5 at room temperature, takes increasing amounts of Cu into solid solution with rising temperature until it extends to Cu_2S at about 425° C, where it becomes the cubic polymorph of chalcocite (Cu_2S). The copper-rich digenite solid solutions react so rapidly that equilibrium is reached in a few minutes, even down to room temperature. Thus, natural assemblages of chalcocite and digenite must, in many cases, represent complete unmixing of a single high-temperature phase. A number of X-ray patterns of natural chalcocites are distinctly different from normal Cu_2S, and they appear to be natural occurrences of a low-temperature synthetic phase the composition of which lies between Cu_9S_5 and Cu_2S.

Composition of water

William Back and I. K. Barnes have concluded that values for pH and bicarbonate determined in the laboratory are not reliable indicators of whether ground water is in chemical equilibrium with calcite. They have also found (Art. 280) that reliable measurement of Eh in ground water in the field requires complete electrical shielding of the meter and electrode assembly. Special precautions are required to prevent air from entering the water before or during measurements.

A potentiometric method of measuring chloride content of ground water has been used by Back (1960a) in field studies. The method uses a sensitive pH meter with a silver–silver chloride electrode and a saturated calomel reference electrode.

The dissolved iron content of ground water and field measurement of pH form a basis for estimating Eh in aquifers. Study of the Eh–pH relationships and other factors governing iron content of water by J. D. Hem (1960) suggest that injection of oxidizing water into an aquifer through a recharge well may cause iron to precipitate from the native water as ferric oxide or as hydroxide. Such precipitates can form for some distance around the injection well and decrease its capacity to take water.

Hem (1961a) has also developed a nomograph that simplifies calculation of ionic strength and ion activities from water analyses in parts per million, and a graph (Art. 415) for computing the proportion of dissolved manganese that is complexed with sulfate or bicarbonate.

In studying the changes occurring in solute concentrations during the progressive wet-grinding of a granitic rock, using surface area increase as a reference criterion, Stanley M. Rogers found that sodium concentrations increase, whereas silica and potassium concentrations decrease.

Chemical equilibria in aquifers

William Back (1961) has applied thermodynamic calculations to the study of chemical equilibria in ground water. By means of field determination of pH and bicarbonate it can be determined whether ground water flowing through limestone areas is saturated with calcium carbonate, in respect to calcite or aragonite.

Application by Back (1960b, c) of the concept of "hydrochemical facies" to the chemical composition of ground water emphasizes that the nature and concentration of ions in solution are determined by the lithology and the ground-water flow pattern of a particular region. Techniques used for mapping hydrochemical facies are modifications of the procedures used in mapping lithofacies.

Geochemical distribution of the elements

In a study of the sulfo-carbonate waters and associated deposits in Deep Springs Lake, Calif.—an ephemeral saline lake—Blair Jones (Art. 83) has identified several zones based on the occurrence of saline minerals, including salt complexes, that are due to sequential precipitation of salts from evaporating lake waters. The sequence of mineral zones in the deposits from lakeshore to center is calcite and (or) aragonite, dolomite, gaylussite, thenardite, and burkeite. Minor elements found in the lake brines in significant quantities include arsenic, boron, bromine, copper, iodine, lithium, phosphorus, strontium, and tungsten.

R. F. Miller and K. W. Retzlaff (Art. 22) have correlated increasing proportions of soluble sodium over calcium and magnesium with the direction of water movement through two deep permeable soils, one a humid residual soil, and the other an arid alluvial soil. Soluble sodium content ranges from 13 to 47 percent in the humid residual soil profile and from 6 to 49 percent in the arid alluvial soil. The observed trends are attributed to ion exchange and to differential salt solubility.

R. A. Krieger and G. E. Hendrickson (1960a, b) report that Greensburg oil field brines from the Laurel dolomite of Silurian age, in the Upper Green River basin, Kentucky, contain from 60,000 to 85,000 ppm of chloride. Brines draining from the oil field have altered the chemical composition of Green River water from an historically calcium bicarbonate type to one of sodium chloride type. At times the chloride content exceeds 1,000 ppm.

Weathering and leaching of spoil banks created by strip mining of coal is a source of acid waters in the Cane Branch basin, McCreary County, Ky. According to J. J. Musser, the affected waters of Cane Branch below the mining area have a pH range of 3.0 to 3.5. Solution of iron, aluminum, and manganese is accelerated. For the period October 1956 to September 1957 the chemical load of Cane Branch (500 tons per square mile per year) consisted of sulfate, 69 percent; calcium and magnesium, 15 percent; iron, aluminum, and maganese together, 9 percent; silica, 3 percent; and other constituents, 4 percent.

E. F. McCarren, J. W. Wark, and J. R. George (Art. 317) demonstrate how acid coal mine wastes to Swatara Creek, Schuylkill County, Pa., are diluted by inflow from the upper and lower Little Swatara Creek, above Jonestown. This stream contains less than 50 ppm of dissolved solids, mostly calcium bicarbonate, whereas overflow mine waters contain more than 800 ppm and have pH values of 3.0 or less.

W. H. Durum, S. G. Heidel, and L. J. Tison (Art. 266) have shown that rivers draining about 8,245,000 square miles and discharging 5,350,000 cubic feet per second of water from all the North American continent yield about 611,000,000 tons of dissolved solids annually to the oceans. This is equivalent to about 116 ppm or an annual load of 74 tons per square mile of drainage area. Contrasting values are 82 tons per square mile for the United States, and 57 tons per square mile for Canada.

In the same study it was observed spectrographically that the minor elements iron, aluminum, strontium, barium, maganese, boron, titanium, copper, chromium, nickel, and phosphorus occur most frequently in the range 1 to 100 micrograms per liter. Lesser amounts of about 15 other minor elements were reported.

FIELD GEOCHEMISTRY AND PETROLOGY

Differentiation of igneous rock series

Studies by G. W. Walker (Art. 200) of volcanic rocks in south-central Oregon have established that soda rhyolites, characterized by quartz, anorthoclase, albite, acmite, riebeckite, and enigmatite, or rhonite, were probably produced by magmatic differentiation, and were erupted from several volcanoes of Miocene or Pliocene age. Prior to this discovery, alkalic volcanic rocks were unknown in this part of Oregon.

R. L. Smith, R. A. Bailey, and C. S. Ross (Art. 340) find that the alkalic-calcic volcanic rocks of the Jemez Mountains, N. Mex., have followed an eruptive-differentiation sequence of basalt–andesite–dacite–rhyodacite–quartz latite–rhyolite. In the culminating rhyolitic phase, concentration, then subsequent depletion, of volatiles produced a succession of ash falls, voluminous ash flows, and finally extrusion of viscous gas-poor domes and flows. This sequence has been observed by Yamasaki [34] in many Japanese volcanoes, and lends further evidence to the concept outlined by Kennedy [35] that the volcanic cycles are related to volatiles in the magma column.

Origin of carbonatites

A study by W. T. Pecora of the Rocky Boy alkalic stock of the Bearpaw Mountains, Mont., reveals a close genetic association of carbonatites with a sericitized nepheline syenite volcanic neck. The carbonatites are composed essentially of orthoclase, biotite, calcite, pyrrhotite, and pyrite, with minor aegirite, apatite, barite, burbankite, ilmenite, zircon, and uranium-rich pyrochlore. They fill fractures in the brecciated intensely sericitized central part, or throat, of the neck. Pecora concludes that the carbonatite liquid was essentially a syenite magma enriched in H_2O, CO_2, and S, and that sericitization by hydrothermal reaction with subsilicic alkalic rocks released abundant Si and Na for later quartz-vein deposition and soda metasomatism.

Late magmatic processes

In a field petrologic study of the Late Triassic Watchung basalt of New Jersey, G. T. Faust has distinguished tectonic joints from cooling joints and has classified the cooling joints into "columnar," "blocky," and "curvilinear" types in order of descending position. The blocky joints seem to be related to thickness of the flows. Curvilinear joints occupy the greatest thickness of most flows and usually extend to the basal contact. These distinctions have proved to be useful aids in determining stratigraphic positions within flows and in mapping structures in the area and elsewhere.

Origin of welded tuffs

As part of a definitive study of ash-flow deposits, R. L. Smith (1960a, b) has defined zones of nonwelding, partial welding and dense welding and superimposed zones of granophyric crystallization, devitrification, vapor-phase crystallization, and fumarolic alteration. Application of these concepts in a detailed stratigraphic study of the Bandelier tuff, Jemez Mountains, N. Mex., has permitted Smith, Ross, and Bailey to separate that formation into two major units, each related to a different caldera source area.

In a preliminary study of the crystal content and chemical composition of welded tuffs from western United States, R. J. Roberts and D. W. Peterson (Art. 320) show that crystal-poor welded tuffs are mostly rhyolitic, whereas crystal-rich welded tuffs are mostly quartz latitic or dacitic. The differences between the two types suggest eruption at different stages in the magmatic cycle of silicic volcanic rocks.

Origin of accretionary lapilli

A comparative study of accretionary lapilli in tuffaceous volcanic rocks in western United States has been completed by J. G. Moore and D. L. Peck. Features of these structures suggest that they form on dry land or only in shallow water, that the volcanic vent was above water, and that lapilli can be used as a key to post-depositional changes that have affected the host rock.

Origin of zeolitic rocks

With the recognition in recent years of the zeolite facies much attention has been focused on the stability relations of zeolite assemblages in slightly metamorphosed sediments and pyroclastic rocks. In a study of the relation of carbonate-quartz-clay mineral assemblages to zeolitic assemblages, E-an Zen has outlined the stability fields of both assemblages, and has found (a) that neither need be metastable, and (b) that their compositional differences are determined by reactions involving CO_2 as well as H_2O.

Origin of glaucophane schists

R. G. Coleman and D. E. Lee have demonstrated that the glaucophane-schist facies is separate and distinct from the greenschist facies. In the Cazadero area, California, they found metamorphic aragonite, having a microscopic fabric symmetry compatible with that of the enclosing schists, in association with spessartine-rich garnet. Although spessartine garnet, hitherto recorded in the chlorite zone of the greenschist facies, indicates that the grade of metamorphism is similar to that of the greenschist facies, the presence of aragonite indicates that higher pressures ($>$4000 bars) are characteristic of the glaucophane schist facies. The fact that the aragonite has not inverted to calcite indicates that although the pressure was high, the temperature must have been relatively low.

Chemical changes in metasomatism

On the basis of modal and chemical analyses of metasomatized rhyolites in the Humboldt Range, Nev., D. B.

[34] Yamasaki, Masao, 1959, Role of water in volcanic eruption: Volcanol. Soc. Japan Bull., v. 3, p. 95–106.

[35] Kennedy, G. C., 1956, Some aspects of the role of water in rock melts: Geol. Soc. America Spec. Paper 62, p. 489–504.

Tatlock (Tatlock, Wallace, and Silberling, 1960), has found field evidence that strikingly substantiates the experimental finding of Hemley[36] for the system K_2O–Al_2O_3–SiO_2–H_2O. From the periphery to the center of the altered rhyolitic area, he finds mineral assemblages ranging from K-feldspar through K-feldspar–muscovite, muscovite, muscovite–pyrophyllite–andalusite, to pyrophyllite–andalusite. These mineralogical changes are paralleled by chemical changes with K_2O increasing toward and Al_2O_3 increasing away from the center of alteration.

Chemical changes in metamorphism

A. E. J. Engel and C. G. Engel (Art. 262) find that hornblendes in the amphibolitic rocks of the northwest Adirondacks undergo systematic changes in chemical composition and color with increasing grade of regional metamorphism. They also find that many high temperature metamorphic hornblendes are deficient in hydroxyl, and do not contain compensating amounts of halogens.

In studying the effects of contact metamorphism on various schistose rocks in Connecticut and North Carolina, Fred Barker (Arts. 268, 270) finds that the mineral assemblages are consistent with Gibbs's phase rule.

Origin of saline and calcium sulfate deposits

W. H. Bradley is studying the geochemical balances of sodium, calcium, and sulfur in the saline member of the Green River formation, Wyoming, and the amounts of these elements brought into the ancient lake basin. He concludes that no unusually sodium-rich source need be postulated to account for the prodigious deposits of trona and other sodium salts occurring in that formation.

C. F. Withington (Art. 410) has proposed that the mottled structures in bedded calcium sulfate deposits originated after deposition but before lithifaction and that they grew in place in bottom sediments by crystallization from concentrated interstitial solutions.

Origin of clays and other sediments

A study by E. W. Tooker of the clay minerals in rocks in the lower part of the Oquirrh formation, Bingham, Utah, demonstrates an association between clay minerals and rock types. In the rocks studied illite is ubiquitous but most abundant in limestone; regular mixed-layer chlorite-montmorillonite is most common in dolomitic limestone and calcareous quartzite; chlorite is dominant in dolomitic quartzite; and kaolinite is found only in quartzite. No appreciable separate montmorillonite phase occurs in any of the rocks. Tooker believes that because specific clay-mineral assemblages occur regularly with specific rock types in this stratigraphic sequence the assemblages were formed in equilibrium with the major rock constituents in the sedimentary environments. (Compare with conclusions of Sigvaldason and White, Art. 331.)

A. E. J. Engel and C. G. Engel are reviewing a variety of information relating to the nature of sedimentary rocks within the framework of continental North America. Their findings to date indicate that the mass of sedimentary rocks exhibits the following secular changes: (a) decrease in graywacke type clastics relative to sandstones and shales, (b) decrease in the ratio of total clastics to total chemical and biochemical precipitates, (c) systematic change in both mineralogical and chemical composition of sediments, including a marked decrease in the ratio Na : K in clastic sediments. These changes in the continent with time reflect the change of its structure from a complex of emergent Precambrian geosynclines like those found at the continental border to a more stable, more granitic mass.

Origin of ores and ore solutions

Analysis of geological and mineralogical relations of hydrothermal thorium deposits in the Wet Mountains, Colo., by George Phair and F. G. Fisher (Art. 293) suggests that such deposits are the by-product of intensive potassic feldspathization of granite. They postulate that thorium, having limited solubility in alkalic solutions, is predisposed to form residual concentrations during feldspathization and, not being accommodated by the growing feldspar, is expelled into the adjacent porous matrix to form enriched protore.

P. M. Bethke, P. B. Barton, Jr., and M. W. Bodine (1960) have studied the time-space relations of ores at Creede, Colo., through extensive use of thick (0.1 to 10 mm) sections of sphalerite. They have been able to establish a detailed "stratigraphy" of the successive growth zones of sphalerite that can be traced for several thousand feet through the ore body. Edwin Roedder (1960b) has studied the fluid inclusion compositions and geothermometry of these ores and has shown that thermal and chemical environments differed from one sphalerite generation to the next.

In a study of the Sulfur Bank, Calif., quicksilver ore deposit, which was clearly formed by hot-spring activity, D. E. White finds that the distribution of ore and gangue minerals is strongly influenced by the water table. Quicksilver was transported almost entirely in water and still is being deposited from nearly neutral water low in sulfide. The present water is chemically and isotopically similar to connate and metamorphic water and is unlike water most clearly related to volcanism.

[36] Hemley, J. J., 1959, Some mineralogical equilibria in the system K_2O–Al_2O_3–SiO_2–H_2O: Amer. Jour. Sci., v. 257, p. 241–270.

The presence of mercury in brines and crude oil from the Cymric field, Kern County, Calif., reported by E. H. Bailey, P. D. Snavely, Jr., and D. E. White (Art. 398), may also have bearing on the origin of quicksilver deposits, as many quicksilver deposits contain significant quantities of hydrocarbons.

Hydrothermal rock alteration

G. E. Sigvaldason and D. E. White (Art. 331) are studying hydrothermal rock alteration as revealed in drill holes at Steamboat Springs, Nev. They find that the mineral assemblages developed are related to composition of water, temperature, and depth and, unlike those at Bingham, Utah (see p. A–78), are virtually independent of the original rock types. The principal hydrothermal minerals encountered are montmorillonite, kaolinite, illite, several chlorites and mixed-layer clays, potassium feldspar, quartz, calcite, pyrite, and pyrrhotite.

Distribution of minor elements

As part of a continuing investigation of the distribution of minor elements in igneous rocks, David Gottfried, Lillie Jenkins, and F. S. Grimaldi (Art. 108) have determined the niobium content of rocks of three contrasting comagmatic suites: the California batholith, the Shonkin Sag laccolith, and the White Mountain (New Hampshire) plutonic-volcanic series. In each of these series niobium increases in the more silicic differentiates. In a related study of the White Mountain plutonic-volcanic series, A. P. Butler (Art. 31), finds that thorium also increases in the more silicic differentiates.

In a detailed investigation of the geochemistry of the Pierre shale, H. A. Tourtelot, L. G. Schultz, and Claud Huffman, Jr. (Art. 253), find that the boron content in bentonites and shales seems to be more closely related to the total amount of clay minerals than to particular clay mineral species.

In a study of the chemical properties of the minor elements found in coals and carbonaceous sediments, Peter Zubovic, Taisia Stadnichenko, and N. B. Sheffey (Art. 411) have characterized the behavior of minor elements in coal-forming environments. They find that partition of elements between organic and inorganic phases and the formation of mineral deposits in such sediments are directly related to ion size and charge, bond configuration, and coordination number.

ORGANIC GEOCHEMISTRY

Investigations in organic geochemistry have application in several fields of geology and hydrology. The work summarized below relates primarily to the composition and structure of certain naturally occurring organic substances. The use of concentrator plants in studies of the incidence of disease is discussed on page A–94, and the use of plants in geochemical and botanical prospecting is discussed on pages A–94, A–95 to A–96.

Origin of kerogen

As one result of comprehensive studies now being made of organic matter in sediments and rocks, I. A. Breger has found that the insoluble organic fraction (kerogen) of certain marine shales consists mainly of humic matter of terrestrial origin rather than organic detritus of marine origin. The fact that such humic matter is not converted to petroleum may explain why rock bodies such as the Chattanooga and the Pierre shales are not important sources of oil.

Biochemical fuel cell

A "biochemical fuel cell" has been devised by F. D. Sisler as a result of observations of electron exchange between marine sediments and the overlying sea water. A laboratory model of the cell produces electrical energy directly from the decomposition of organic matter by bacteria. The cell is composed of two sections, an anode and a cathode, each containing an inert electrode connected by an ion-diffusion bridge. A mixture of sea water containing organic matter as fuel and bacterial cells (or enzymes) as a catalyst is placed in the anode section. The cathode contains sea water and oxygen. The oxygen and organic matter could be furnished inexpensively by live algae which would utilize solar energy. A great variety of organic waste materials could also be used as an energy source.

Iron in water and plant materials

The average iron content of aquatic plants studied by E. T. Oborn (1960b) was 4.99 mg per g of dry matter. This is more than 10 times the iron content of most land plants but is similar to the iron content of primitive land species such as lichen. When aquatic plants die and decay they may add considerable amounts of iron to the water in which they have grown.

Microbiotic activity greatly facilitates the solution of iron from soil. As a result, dissolved iron can be added to ground water by recharge passing through the soil zone. Work by Oborn and J. D. Hem (1961) has shown that as much as 10 percent of the total iron content of mixtures of soil and organic matter was brought into solution after two weeks of incubation. Amounts of iron dissolved in the absence of organic matter or bacterial action were smaller by a factor of 100 or more.

Leaves of trees growing in areas disturbed by strip mining in Kentucky were found by Oborn (Art. 119) to contain more iron than leaves of trees in nearby undisturbed areas. Where strip mining has taken place in this area, the iron content of water has increased.

ISOTOPE AND NUCLEAR STUDIES

Isotope and nuclear studies provide information needed in many different fields of geology and hydrology, ranging from studies of the structure and composition of minerals to determinations of the length of divisions in the geologic time scale. Many such studies are summarized below. Other related studies are summarized under other headings as follows: radioactive materials, pages A–6 to A–7; studies related to disposal of radioactive wastes, page A–94; and application of isotope geology to exploration, page A–96.

GEOCHRONOLOGY

The application of radioactivity dating methods to geologic problems is rapidly expanding. Refinements in methods now permit age determinations to be made on the same mineral or rock by two or more techniques as well as the dating of a number of mineral components from the same rock.

Lead-alpha age measurements

The lead-alpha method, because of its simplicity, has been applied to many geologic problems. Refinements in the technique for spectrochemical determination of lead in zircons have been reported in a paper by H. J. Rose, Jr., and T. W. Stern (1960a, b). The method has been further improved by X-ray fluorescence determination of the Th/U ratios of zircon. The Th/U ratios determined in this way by Harry Rose, Jr., and F. J. Flanagan are in good agreement with ratios determined by the isotope-dilution method.

Lead-alpha ages of 25 to 30 m.y. (million years) were obtained by M. Grünenfelder and T. W. Stern (1960) on zircon concentrates from the Bergell granite, an intrusive body that cuts the Pennine nappe systems of the southeastern Swiss Alps.

Three granitic intrusives in northern and central Chile have been determined to be of pre-Jurassic, Jurassic, and Cretaceous ages, respectively, on the basis of lead-alpha age measurements on 11 zircon concentrates (Ruiz, Segerstrom, Aguirre, Corvalan, Rose, and Stern, 1960).

Lead-alpha age determinations on zircons from a variety of rocks have aided in interpreting the complicated geologic history of a part of the Carolina Piedmont (Overstreet, Bell, Rose, and Stern, Art. 45).

Potassium-argon, rubidium-strontium, and uranium-lead methods

Wherever possible the lead-alpha ages on zircons are now being supplemented by potassium-argon age determinations on micas and by rubidium-strontium age determinations on micas, feldspars, and whole rock samples.

Rb-Sr age determinations by Carl Hedge on K-feldspar and whole rock samples of granite and granite gneiss from the Holy Cross quadrangle, Colorado, indicate that the time of origin was about 1700 million years ago. Rb-Sr ages on micas from granites and pegmatities in this area agree with the K-Ar ages determined by R. Pearson and H. Thomas and range from 1100 to 1400 m.y. The Laramide orogeny is represented by small plutons dated at 60–70 m.y.

Potassium-argon and rubidium-strontium age determinations by H. Faul, H. Thomas, P. L. D. Elmore, and W. W. Brannock indicate a complex history of intrusion and metamorphism in Maine. Thermal events occurred in this region during the Devonian (400–350 m.y.), the Permian (270–250 m.y.), and during Jurassic time (180–130 m.y.). Lead-alpha ages, available for many of these samples, commonly are higher than the K-Ar and Rb-Sr ages and suggest that certain of the dated rocks originated much earlier. Evidence of the Grenville orogeny (approximately 1000 m.y.) in southeastern Vermont is suggested by some of the age determinations.

Rubidium-strontium age determinations by R. W. Kistler of Sierra Nevada rocks range from 75 to 100 m.y. Age determinations by Rb-Sr and K-Ar methods are being used to determine the sequence of intrusions in a regional study by P. Bateman and Kistler.

H. Thomas and H. Faul, in collaboration with K. Przewlocki and W. Magda of Kraków, Poland, have dated granite from the Karkonosze and Kudowa plutons in southwestern Poland at 300-320 m.y. Rb-Sr ages of approximately 1400 m.y. were found for mica from cores of the buried crystalline basement in northeastern Poland. The basement gneisses may be part of the Ukrainian Shield.

Graphic and algebraic solutions of the discordant lead-uranium age problem have been presented by L. R. Stieff and T. W. Stern (1961). A. P. Pierce (Art. 402) has continued his study of radiation damage and isotopic disequilibria in uranium-bearing asphaltic nodules.

Carbon-14 age determinations

Meyer Rubin and S. M. Berthold (1961) have presented a list of radio-carbon dates determined during the past year. These dates have been useful in recording changes in sea level associated with changes in climate during the last 40,000 years, and in dating volcanic flows, ash falls, glacial deposits, and fluvial deposits.

Protactinium-thorium dating of deep-sea cores

Studies of the Pa^{231}/Th^{230} dating method by Rosholt, Emiliani, Geiss, Koczy, and Wangersky (1961) provide a reliable means of extending the time scale from the present to about 175,000 years ago. The Pa^{231}/Th^{230} method has been applied to study of two cores from the Caribbean, approximately 600 kilometers apart. The results of the dating of samples from these cores agree with the carbon-14 chronology, but beyond the radiocarbon range the Pa^{231}/Th^{230} measurements indicate that the last interglacial age began about 100,000 years ago and lasted about 35,000 years.

LIGHT STABLE ISOTOPES

Deuterium in hydrous silicates and volcanic glass

The amount of water and its deuterium content in biotite, hornblende, and chlorite are being investigated by Betsy Levin and Irving Friedman with the cooperation of John Godfrey of the Research Council of Alberta. The water is extracted by heating the minerals to 1500° C in a vacuum. Hornblende concentrates from various rocks of the Sierra Nevada batholith show similar water contents, whereas biotite concentrates show considerable variation. A similar relationship is found for hornblende and biotite concentrates from rocks of the southern California batholithic complex. The water and deuterium contents of the biotite from rocks of the complex are related to rock type and SiO_2 content. In general, the deuterium content of water extracted from chlorite is similar to that from biotite in the same rock.

Irving Friedman and K. J. Murata have started an investigation of water and deuterium in basaltic glass collected during the 1959-60 eruption of Kilauea. The glasses show progressive enrichment in water content with increasing SiO_2 and K_2O contents. The deuterium concentration varies inversely with water content of the glass.

Fractionation of oxygen isotopes between dolomite and calcite

Wayne Hall and Irving Friedman find that, in the system calcite and dolomite in equilibrium with water at low temperatures, the calcite and dolomite have the same O^{18}/O^{16} ratio within ± 0.2 percent. This was determined by analyzing many samples of Mississippian rocks from Illinois and Wisconsin, as well as partially dolomitized limestone from California and Nevada. Samples of finely intergrown calcite and dolomite ranging from pure calcite to pure dolomite give the same O^{18}/O^{16} and C^{13}/C^{12} analyses, irrespective of the proportions of calcite to dolomite. Dolomite separated from the mixtures by leaching of the calcite also gives the same O^{18}/O^{16} and C^{13}/C^{12} values. Use of oxygen isotopes in studies of lead-zinc and fluorite deposits of the Upper Mississippi Valley is described on page A–96.

Fractionation of oxygen isotopes as a geologic thermometer

The fractionation of oxygen isotopes between co-precipitated minerals as a function of temperature is being investigated by R. N. Clayton and H. L. James. From analyses of minerals formed in equilibrium in natural environments several tentative equations have been derived relating temperature (T, in degrees Kelvin) to the equilibrium constant (K); for example, for an equilibrium pair quartz (Q)—magnetite (M):

$$ln\ K_{QM} = 3216\ T^{-2}$$

Isotopic analyses have been made of mineral pairs from Precambrian iron-formations in different metamorphic zones of the Lake Superior region. The temperatures obtained from the data are consistent and geologically reasonable for rocks formed in the chlorite, biotite, and garnet zones; maximum values are as follows:

Chlorite zone	200° C
Biotite zone	275° C
Garnet zone	350° C

The apparent temperatures of formation of rocks formed at higher metamorphic levels are inconsistent both within themselves and with geologically estimated temperatures of origin; this is attributed to retrograde alteration during the period of temperature decline.

LEAD ISOTOPES

R. S. Cannon, A. P. Pierce, J. C. Antweiler, and K. L. Buck (1961) have summarized the available data on the isotopic variations of ore-lead and their relations to processes of ore deposition. In a continuation of their studies, systematic variations in the relative abundance of lead isotopes in successive growth zones of a single crystal of galena from the Picher-Miami area, Oklahoma, have been related to changes in ore-forming solutions during mineralization.

STUDIES OF VOLCANIC GLASS

Analyses of water and of fluorine in rhyolitic glass by Irving Friedman and Joseph Harris (Art. 258) show that during hydration of obsidian the fluorine content is not appreciably affected. The fluorine content of glasses appears to be remarkably uniform within a magmatic province, but changes from province to province. H. A. Powers (Art. 111) has used chlorine-fluorine content as a criterion in correlating beds of volcanic ash in the Snake River Plain, Idaho.

William Long and Irving Friedman are studying the effects of the hydration of obsidian at 400° C with different water pressures. The refractive index of obsidian increases with the water content in the range of 0.1 to 1 percent of H_2O, but then levels off and decreases with water content in range 2 to 4 percent.

R. L. Smith, I. Friedman, and W. Long are continuing experimental studies on welded tuffs. The rates of welding and compaction of rhyolitic ash and pumice were determined as a function of water pressure (0 to 300 psi), temperature (435° to 835° C), and load (up to 528 psi).

SOLID-STATE STUDIES

Luminescence and thermoluminescence studies

In a study of the mechanism of luminescence due to alpha particles in minerals, P. Martinez and F. Senftle have determined the variation of the intensity and the decay time of the luminescent pulses with temperature for pure cesium iodide and also for cesium iodide containing about 0.1 percent of thallium as an impurity. Thermal luminescence measurements show that the scintillation produced in the activated crystals results from an electron-trapping mechanism.

Radiation-damage studies

T. Pankey and F. E. Senftle are investigating natural radiation-damage processes in zircon and uraninite. Because radiation damage changes the oxidation state of the iron in the mineral, the natural iron impurity can be used as a tracer. The different oxidation states have specific magnetic properties, and hence the effects of damage can be analyzed by magnetic measurements. By use of such an analysis they have found that about 1,500 atoms are displaced in zircon by a single alpha particle and the recoil of the uranium nucleus. Thermomagnetic measurements on pure iron oxides verify the results found in zircon and uraninite.

Magnetic properties of ice

In a study of the magnetic properties of cancer cells, F. E. Senftle and Arthur Thorpe (1961) have discovered that an observed magnetic difference between frozen cancer cells and frozen normal cells is due to the state of ice in the cells. Amorphous ice forms in normal cells and crystalline ice forms in cancer cells. In a continuation of this research they have discovered that water can be frozen so quickly that no crystal structure develops. The magnetic properties of rapidly frozen, amorphous ice and crystalline ice are almost the same as those determined for the corresponding kinds of ice in normal and malignant tumor tissue.

The amorphous ice that forms in normal tissue can be explained by the rapid cooling brought about by the large effective surface area of the cells. In contrast, the water in tumor tissue apparently has a smaller effective surface area. The cooling is therefore slower and only crystalline ice can form. These findings have application in the study of hydrous minerals.

DEUTERIUM AND TRITIUM IN FLUIDS

The origin, past history, and movements of water can frequently be determined by studies of the deuterium and tritium contents. In particular, natural tritium may be used to estimate the age of water up to about 50 years, and fallout tritium provides a starting date for measurements of recent water movements involving a few months or years.

Tritium measurement technique

The measurement of tritium in water consists of four operations—electrolytic enrichment of the sample, measurement of deuterium, conversion of the sample to gas, and lo wbackground counting of the tritium radioactivity. After research into the effects of current density, voltage, and temperature, L. L. Thatcher has designed an electrolysis plant that achieves 75 percent (± 5 percent) tritium recovery when electrolyzing from 200 ml to 1 ml under controlled current and low temperature conditions. Counting research involved analysis of various gaseous quenching agents for their ability to minimize multiple discharge in a hydrogen atmosphere. Ethyl and methyl ethers and ethylene were found to be superior to propane, acetone, ethyl alcohol, propylene, and benzene. Dimethyl ether shows the curious effect of superior quenching ability at higher hydrogen pressures. Below 20 cm of hydrogen the dimethyl ether was ineffective but at 2 atmospheres pressure it was the most effective. Ethyl ether is effective at the low pressures. These improvements in electrolysis and counting techniques permit measurement to ± 10 percent error on a routine basis.

Fallout studies

In a joint project with the U.S. Weather Bureau, fallout of tritium from the early 1958 weapons test in the Pacific was measured at 12 stations extending in a northwesterly arc from Puerto Rico to Alaska. Sample collection began in early April before the American tests series commenced. Fallout levels in the interior of the country, however, were already up to 200 tritium units (1 TU $=1$ T atom/10^{18} H atoms). A further increase to about 500 TU was observed in May and June. In July, when the sampling ended, the decay side of the fallout curve had not yet been reached.

Central inland locations had the highest average tritium levels, about 500 TU through the peak fallout period, and coastal locations had the lowest average levels—about 100 TU. This difference is attributed to the dilution of the fallout by the relatively dead oceanic moisture; confirmation of this is given by the amount of chloride in precipitation, which is uniformly high along the coast and at a minimum inland.

This study shows that tritium fallout is very unevenly distributed and is not uniform for the country.

At the Wharton Tract in New Jersey, Carlston, Thatcher, and Rhodehamel (1960), have found through studies of tritium that virtually all the ground-water discharge into the Mullica River entered laterally from its bank and just below the water table. This supports the deduction that streams in areas of horizontally bedded sediments receive most of their base-flow drainage from beds lying above the bottom of the stream.

Arabian studies

Studies in Arabia by Glen F. Brown have established that in general the Arabian rainfall has followed the same tritium pattern as that of the United States with high values in 1958 and the spring of 1959. Tritium, apparently of natural origin, has been measured by L. L. Thatcher in water from wells in the Wadi alluvium, and ages of the order of 10 years have been established. No tritium could be detected in water from wells penetrating deep aquifers such as the Minjur and Khobar formations, which means that the water has been below the surface for more than 50 years. Some of these samples may have been below the surface for as much as 20,000 years according to carbon-14 analyses by Meyer Rubin.

Model studies

Interpretation of tritium data requires knowledge of the physical and chemical isotopic effects of the environment on tritium behavior, which is difficult to analyze in field studies because of the complex interaction of all factors. Therefore, these effects have been analyzed independently by a series of laboratory model studies.

In a small model at controlled temperature it was found that the evaporation fractionation decreased with temperature rise. At room temperature Price's value for tritium fractionation of 0.85 between the vapor and the liquid was confirmed.

The exchange of HTO with H_2O in montmorillonite was found to be attended by little fractionation, which shows that the adsorption of tritium by clays is relatively unimportant in problems of groundwater movement.

Laboratory tests by Thatcher (Art. 432) on a number of dyes showed several that behaved with relatively little adsorptive holdup. Fast Crimson, in particular, performed in a manner analogous to tritium in montmorillonite column tests. This dye seems to be a good visual tracer to accompany tritium in hydrologic laboratory model tests.

DISTRIBUTION OF RADIONUCLIDES IN WATER

Knowledge of the occurrence and distribution of radioactive elements in surface and ground water bears on many problems relating to geochemical and hydrologic processes, disposal of radioactive wastes, and public health.

In a reconnaissance investigation of the occurrence and distribution of uranium and radium in ground waters of the United States, R. C. Scott and F. B. Barker (Art. 414) found that the concentrations of radium were unusually high ($>$3.3 picocuries per liter) in: (a) formations of Cambrian and Ordovician age in the North Central States, (b) the Roubidoux and Cotter formations in Kansas and Oklahoma, and (c) the Cheyenne sandstone member of the Purgatoire formation in southwestern Colorado.

The concentrations of radium in water within a formation generally increase in the presumed direction of ground-water movement and may be a result of the slow flushing of radioelements.

F. B. Barker and R. C. Scott (Art. 128) have found that concentrations of uranium and radium in ground water from individual terranes of the Pacific Northwest tend to be distributed according to log-normal probability laws. The geometric mean of the distribution is controlled by both geologic and climatic factors. Concentrations of these radioelements tend to be higher in water from the more silicic terranes. In regions of high annual precipitation the concentrations are lower than in semiarid regions. Agricultural development of the Snake River Plain apparently has resulted in higher concentrations of uranium in most water of the area, but has had little effect on the concentrations of radium.

In studies of the concentration of radium and uranium and amount of radioactivity in ground water from Rainier Mesa, Nevada Test Site, Alfred Clebsch and F. B. Barker (1960) have found that the natural level of beta activity in the ground water of the area is less than 25 picocuries per liter. (See also p. A–90.)

HYDRAULIC AND HYDROLOGIC STUDIES

Studies of amounts and movements of water, both on the surface and underground, are important in planning flood control, hydro-electric and municipal water supply projects, in studies of contamination, and in development of new supplies of water for present and future use. Most of the hydraulic and hydrologic studies carried on during the year were directly applicable to work in individual regions or on particular topics and are described in other parts of this report. A few findings of broader application are summarized below.

OPEN-CHANNEL HYDRAULICS AND FLUVIAL SEDIMENTS

Many aspects of open-channel flow have been studied by analysis of laboratory and field observations. Included are studies of steady and unsteady flow in stable and unstable channels of uniform or gradually varied configuration, flume studies, and studies of the effects of urbanization on the amount of sediment in streams.

Distribution of velocity

By laboratory study, H. J. Tracy and C. M. Lester have defined the distribution of velocity in smooth rectangular channels in terms of the average shear on the bed and the aspect ratio of the channel. Within the zone of influence of the side walls, the maximum velocity on a vertical profile is below the water surface. Outside this zone the vertical velocity profile follows the logarithmic law advanced by Karman and Prandtl.

Resistance to flow

The relation between the Manning roughness coefficient and the Froude number or energy slope developed by C. M. Lester (Art. 159) is identical to that predicted by a resistance equation of the Karman-Prandtl form, if the viscosity is constant. In the general case, the coefficient for a smooth channel varies with the Reynolds number and the hydraulic radius.

By laboratory studies W. W. Emmett (Art. 158) has shown that piezometric measurements of depth of flow in open channels are always greater than actual depth because of vortex action in the piezometer hole. The vortex action and the amount of error increases as the hole size or the velocity increases. The error ranges typically in supercritical flow from 1 to 6 percent.

H. J. Koloseus and J. Davidian (Art. 12) have defined the resistance to flow of cubical roughness elements in terms of the relative height and concentration of the cubes. The equation that expresses the relation is similar to the Nikuradse equation for sand-roughened pipes. The height and the concentration of roughness elements are equally important in determining the overall resistance to flow.

Boundary form and resistance to flow in alluvial channels

The forms of bed roughness that may occur in alluvial channels as the boundary shear stress is increased have been classified by D. B. Simons and E. V. Richardson as ripples, ripples superposed on dunes, dunes, the transition zone in which the dunes are eliminated, plane bed, symmetrical sand waves, and antidunes. When the bed roughness consists of ripples, ripples superposed on dunes, or dunes, the undulations induced in the water surface are out of phase with the bed roughness and the resistance to flow is relatively large. With these conditions, flow is said to be in the lower regime of flow. After the transition zone is passed and the forms of bed roughness become plane bed, symmetrical sand waves, and antidunes, the resistance to flow is relatively small and flow is said to be in the upper regime. Thus, the regime of flow is controlled by the form of bed roughness and resistance to flow.

Changes in slope, fall velocity of sediment, or depth of water can change the form of bed roughness, the resistance to flow, and the sediment discharge.

Laboratory studies by Simons and others (Art. 165) have demonstrated that changes in the form of bed roughness and resistance to flow significantly affect stage-discharge and depth-discharge relations. The maximum effect occurs when the bed roughness changes from the lower regime condition of dune to the upper regime of plane bed, symmetrical sand waves, and antidunes.

Significance of fine sediment on flow phenomena in alluvial channels

An increase in the concentration of fine silt and clay in streams increases the apparent viscosity and specific gravity of the stream liquid, and thus decreases the fall velocity of the bed-material particles. Haushild and others (Art. 300) have shown that at 20° C a 5-percent (by weight) aqueous dispersion of bentonite is about 2.5 times more viscous than distilled water. They have also shown that a decrease in fall velocity increases bed roughness and resistance to flow, and decreases the amount of sediment transported.

Effects of temperature on flow phenomena in alluvial channels

D. W. Hubbell and others (Art. 301) have verified by flume experiments that an increase in the temperature of a stream liquid decreases its viscosity and thereby increases the fall velocity of the bed material. If the increase in temperature and the concomitant increase in fall velocity are sufficiently large, a plane bed may be changed to a dune bed, thereby increasing resistance to flow and decreasing the amount of material transported.

Effect of depth of flow on total discharge of bed material

Computations made by B. R. Colby and D. W. Hubbell (1961) with the Einstein procedure and with an empirical analysis of data from flumes and natural streams, show that at constant low mean velocity an increase in depth reduces the bed-material discharge; whereas, at constant high mean velocity the effect of depth is reversed. At some intermediate velocity, the effect of changes in depth is usually small, but the depth effect is large throughout the usual range of significant flows in natural streams.

Solution of unsteady-flow problems

R. A. Baltzer and J. Shen (Art. 162) have developed a solution for a system of unsteady-flow equations by means of power-series expansions through an iteration process. Results of computations for discharges through a reach of the Sacramento River compare closely with the measured discharges.

Detailed measurements of velocity during a tidal cycle on the Delaware River were obtained by E. G. Miller. He found that the mean velocity of flow in the cross section could be related to velocity at a single point. Thus, a continuous record of tidal discharge can be obtained from continuous records of point velocity and stage.

Size and distribution of bed material in the Middle Rio Grande, New Mexico

An analysis of stream-bed material from the Middle Rio Grande at eight sites in a 190-mile reach of river between Otiwi Bridge near San Ildefonso, and San Marcial, N. Mex., by C. F. Nordin and J. K. Culbertson (Art. 265) showed that the bed material ranged from sand and gravel in the upper reaches to sand in the lower reaches. Analysis of the samples indicates that the size distribution of bed material in the lower reaches of the river is relatively independent of flow. In the upper reaches, the characteristics of the bed material changed with discharge. Above 2,000 cubic feet per second, the median diameter of the bed material increased with increase in discharge. Below 2,000 cubic feet per second, the size distribution of bed materials was relatively independent of flow. Also, the bed material in the upper reaches had a bimodal distribution.

Effects of urbanization on the supply of fluvial sediment

H. P. Guy has appraised quantitatively the influence of urbanization on the amount of sediment moved by streams. In rural areas, the concentration of suspended sediment during periods of runoff usually ranges from 200 to 400 ppm. During the period of transition to an urban area when houses are being built and streets are being graded, the amount of suspended sediment in periods of runoff is very high, and may average as much as 36,000 ppm. Usually, a year or two after the development on a given area has been completed, the sediment yield declines to a small fraction of that occurring during construction.

SURFACE-WATER HYDROLOGY

Surface-water hydrology involves measurements of streamflow, and parallel studies of the relations between streamflow and the characteristics of drainage basins and meteorologic factors. The establishment of such relations will enable streamflow to be predicted from physical and meteorologic factors alone. It will also lead to the prediction of changes in streamflow caused by changes in physical conditions, such as changes in land use or the degree of urbanization.

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Errors in streamflow measurement

In examining the accuracy of current-meter measurements, I. E. Anderson (Art. 161) has found that the total error attributable to assumptions involved in the use of the current meter is less than 3 percent for two-thirds of measurements made by standard methods.

Use of precipitation in analysis of runoff data

The relation between runoff in two drainage basins is often used to fill in missing periods of record or to extend the length of record for one of the basins. The relation can be improved and the length of streamflow record greatly extended by also considering differences in precipitation (Schneider, Art. 9).

H. C. Riggs (Art. 42) has used a relation of annual minimum streamflow with two precipitation indices to demonstrate that the three lowest annual minimum periods of streamflow on the Tallapoosa River, Ala., during a relatively short period of record were probably also the three lowest in a longer period covered by the precipitation record.

Low flow

A study by Riggs (Art. 10) of annual minimum 7-day average flows of streams in the eastern United States has led to a generalized relation that defines the 20-year low in terms of the 2-year low, the drainage-area size, and the slope of the recession curve of discharge. This study was based on 47 stations; the relations developed were applied to 61 other stations in widespread parts of the United States and Turkey and seem to fit equally well wherever tested.

Peak flow

M. A. Benson (1961) investigated the relation of peak discharge to hydrologic characteristics in a humid region in New England. Annual momentary peak discharges of recurrence intervals ranging from 1.2 to 300 years were found to vary with six topographic and climatic factors. D. R. Dawdy (Art. 160) has found that the ratio of a flood of given recurrence interval to the mean or median annual flood varies inversely with the size of the drainage area.

STATISTICAL METHODS

Effect of interstation correlation

N. C. Matalas and M. A. Benson have studied the effect of interstation correlation (as, for example, where annual peak discharges on several basins are caused by the same storms) on regression relations between peak discharges and a hydrologic factor. They have demonstrated on statistical grounds that interdependence between the discharges for different stations increases the variance of the regression constant, decreases the variance of the regression coefficient, and may decrease but usually increases the variance of a predicted value of the dependent variable. These findings shed light on the reliability of predicted streamflow of a given recurrence interval and relations of streamflow with hydrologic characteristics.

Statistical properties of a runoff precipitation relationship

An investigation has been made by N. C. Matalas of the influence of the water-retardation characteristics of a river basin on the distribution of the runoff. The runoff was taken to be generated by a moving average of the effective precipitation where the time interval of the moving average is assumed to be equal to the carryover period, which is a function of the water-retardation characteristics of the river basin.

The probability distribution of the runoff was found to be a function of the time interval of the carryover period. Since the water-retardation characteristics vary from one river basin to another, even though the characteristics of the effective precipitation may be the same for each river basin, the probability distribution of the runoff is not the same for all river basins.

Owing to the carryover period, the runoff is nonrandomly distributed in time. The serial correlation coefficients measuring the nonrandomness of the runoff are functions of the coefficients of the moving average model under the assumption that the effective precipitation is randomly distributed in time.

Statistical evaluation of tree-ring data

Trees growing on well-drained sites where rainfall is the limiting climatic factor influencing growth, constitute a source of hydrologic information.

In an investigation of the statistical characteristics of tree-ring indices, N. C. Matalas has shown that at any given time the mean annual growth is proportional to the standard deviation. Thus, the coefficient of variation serves as a measure of the sensitivity of growth to variable hydrologic conditions. Matalas also showed that averaging of indices for several trees results in a loss of information, and that tree-ring indices are nonrandomly distributed in time. Correlogram and power spectra analyses made for a 450-year old pinon pine from the upper Gila River basin near Beaverhead, N. Mex., indicated that the nonrandomness was due to a "storage" effect rather than to ridden periodicities. The serial correlation coefficients of tree-ring indices were found to be much larger than those for annual rainfall and to varry with the species. This variation suggests that the biological components influencing growth contribute to the nonrandomness of the tree-ring indices.

Low flow probability distribution

Analyses were made by N. C. Matalas to determine which theoretical probability distribution best fitted observed values of low flow and to determine the desirability of estimating the parameters of theoretical probability distributions by the method of maximum likelihood. Four theoretical probability distributions were studied: (a) Gumbel's limited distribution of the smallest value; (b) the Pearson Type III distribution; (c) the Pearson Type V distribution; and (d) the 3-Parameter Log-Normal distribution.

Applicability of each of these four theoretical probability distributions to low-flow data, was measured by two criteria. The first criterion was based on the relation between the observed minimum low flow and the lower limit of the theoretical probability distribution. The second criterion was based on the observed relation between skewness and kurtosis with respect to the relation between skewness and kurtosis for the theoretical probability distribution. The Gumbel and the Pearson Type III distributions were found equally applicable and more representative than the Pearson Type V or the 3-Parameter Log-Normal distributions.

The above conclusions were based on moment estimates of the various statistical parameters. An alternate method of estimating the parameters so that their variances are a minimum is that of maximum likelihood. The variances of the moment and maximum likelihood estimates are functions of the skewness of the data. The average skewness for the low-flow data was found to be approximately 1; whereby, the variances of the moment estimates were nearly twice as large as the variances of the maximum likelihood estimates. Thus, the method of moments utilizes only half of the available information in a set of low-flow data. On the other hand, the complexity of the method of maximum likelihod requires the use of high-speed electronic computers.

Reservoir storage—general solution of a queue model

The application of queuing theory to reservoir storage problems usually leads to a set of simultaneous linear equations that must be solved for each specific case. By assuming that random inflows during successive units of time are approximated by a trinomial probability distribution, W. B. Langbein (Art. 298) derived a general solution for the set of simultaneous linear equations. Calculations for the probability of spilling and being empty are based on two cases—a normal distribution of inflow, and a logarithmic normal distribution of inflow having a skew equal to 1.0.

Fluctuation of annual river flows

V. M. Yevdjevich has made a statistical study of the fluctuation of annual runoff and effective annual rainfall, based on records for 140 river gaging stations throughout the world. A comparison was made of the statistical properties of annual runoff and effective annual rainfall with the statistical properties of random time series and time series generated by a moving-average process. Yevdjevich concludes that much of the difference between the observed hydrologic time series and purely random time series can be attributed to regression effects due to the year-end carryover of water, snow, and ice, and to the inconsistency and nonhomogeneity of the data.

MECHANICS OF FLOW THROUGH POROUS MEDIA

A theory of infiltration by W. O. Smith attributes fluid movement through unsaturated porous media to a process of layering and sheet flow. The process is believed to be influenced by the detachment of capillary bodies as movement progresses toward the water table. R. W. Stallman (Art. 28) has completed a preliminary design of an electric analog to simulate terms in the equation that describes one-dimensional flow of fluid through unsaturated porous media. The analog will permit analysis of fluid movement through nonhomogeneous profiles under various boundary conditions.

H. R. Henry (1960a, b) has derived mathematical formulas for describing the distribution of head and salinity in the fresh-water–salt-water zone of dispersion in a confined coastal aquifer in which there is steady seaward flow of fresh water. The results confirm a cyclic flow of salt water from the sea floor into the zone of diffusion and back to the sea, thereby lessening the extent to which salt water occupies the aquifer. W. K. Kulp and H. H. Cooper have evaluated, through laboratory experimentation and analysis, the dispersion coefficients associated with saturated granular materials subject to reciprocative fluid movement. The results show that the coefficients for this type of flow are virtually the same as for unidirectional flow.

H. E. Skibitzke (1960c) has demonstrated with hydraulic experiments on artificial sandstone models that three-dimensional fluid flow through heterogeneous regions in porous media is characterized by considerable intertwining of the flow lines. He concludes that the heterogeneity causes the fluid to spread out as it moves and that the ordinary processes of diffusion and dispersion are not significant by comparison.

J. A. da Costa and R. R. Bennett (1960) have derived the mathematical equations describing the steady-state flow patterns in the vicinity of a pair of wells, one of which is recharging and the other is discharging, in a region of preexisting one-dimensional ground-water flow. The equations permit determination of the interflow between the recharging and discharging wells in terms of the orientation of the wells with respect to the direction of preexisting regional flow, the rate of recharge or discharge per unit length of well bore, the distance between the two wells, and the preexisting velocity of the regional ground-water flow.

LIMNOLOGICAL PROBLEMS

Salinity of closed lakes

In some closed lakes the salt in solution is less than 1 percent by weight; in others, the salt in solution exceeds 25 percent. In all closed lakes the tonnage of dissolved salts is substantially less than the total input of salts over the life of the lake. In a study of 25 lakes in many parts of the world, W. B. Langbein has found that a significant part of differences in salinity can be explained in terms of lake area, the variation in lake area, mean depth, rate of evaporation, tributary area, and the volume between the lake level and the level of overflow.

Preliminary analyses by L. B. Laird of water from Lake Abert, a closed lake in south-central Oregon, show concentrations of dissolved solids ranging from 10,000 to more than 50,000 parts per million. Sodium, carbonate, bicarbonate, and chloride are the principal constituents. Significant amounts of silica, potassium, bromide, phosphate, and boron are also present.

Pleistocene lake levels as indicators of climatic shifts

The ratios of precipitation to evaporation in the Basin and Range Province during Pleistocene time have been determined by C. T. Snyder and W. B. Langbein to have been at least 35 percent greater than present ratios based on a consideration of the high levels attained by former Pleistocene lakes.

EVAPOTRANSPIRATION

The energy-budget method of measuring evapotranspiration has been tested by O. E. Leppanen and G. E. Harbeck, Jr. (1960) at a site in Nebraska. A water-budget control was used so that evapotranspiration could be determined from measurements of rainfall and changes in soil-moisture storage. There was no runoff from the area. Ground water was too deep to supply any water to the vegetation. Evapotranspiration computed from the energy budget was somewhat greater than that computed by the water budget. The accuracy of the evapotranspiration figures computed by the energy-budget method was found to depend to a large extent on the accuracy with which the interchange of sensible heat between the atmosphere and the vegetation can be measured.

GEOLOGY AND HYDROLOGY APPLIED TO PROBLEMS IN THE FIELD OF ENGINEERING

Some of the Survey's work is designed to provide geologic and hydrologic information that is directly applicable to the solution of engineering problems, such as construction of dams, roads, public buildings, damage caused by earthquakes, landslides, and erosion, or studies in connection with underground testing of nuclear explosives. A few examples of such applications, some done at the request of other Government agencies and some as outgrowths of the Survey's regular program, are described here. In addition to these specific applications, most of the Survey's maps and reports contain information that is useful to engineers.

CONSTRUCTION PROBLEMS

The Survey's work on construction problems during the past year has been concentrated on urban and highway construction, tunnel investigations, and related research.

Urban geology

As a byproduct of urban investigations that have been in progress in the San Francisco Bay region for some years, records of 456 wells and test borings made on the east side of San Francisco Bay were released to the public (Weaver and Radbruch, 1960).

In the cities of Omaha, Nebr., and Council Bluffs, Iowa, R. D. Miller has reported the discovery, by means of auger drilling, of a limestone bench within reach of end-bearing piles beneath the flood plain alluvium of the Missouri River. With alleviation of flood threats by the completion of major dams upstream, this discovery may well change hitherto useless land into suitable sites for industrial plants. D. J. Varnes made an analysis of full-scale load tests of foundation caissons set in sandy silty gravel at the Air Force Academy site near Colorado Springs, Colo. This analysis showed that settlement cannot be predicted according to the classical theory of consolidation but is better handled by the theory of creep, and is closely analogous to chemical kinetic-rate theory. It was found that some tests very nearly followed Andrade's law of creep and that most approached a rate at which settlement varied linearly with the logarithm of time. Extrapolation of the tests to 10 million minutes indicated a linear relation between log load and log settlement.

Highway geology in Alaska

Contributing to studies of highway geology in Alaska, which are carried on in cooperation with the Bureau of Public Roads, T. L. Péwé and S. W. Holmes have mapped the Mount Hayes D–3 and D–4 quadrangles near Big Delta. They found that late Pleistocene moraines have been displaced as much as 15 feet by recently active faults, a factor that must be taken into account by road builders. They also report that the great depth of seasonal freezing in gravel outwash plains may be mistaken for permafrost.

Other highway geology studies in the Yukon-Koyukuk lowland by F. R. Weber and T. L. Péwé (Art. 419) will aid the Bureau of Public Roads in road location and construction through a most difficult and complex area of perennially frozen ground.

Destruction by flood of the Sheep Creek bridge on the Richardson Highway focussed attention on the threat of floods from sudden drainage of ice-dammed lakes in the Chugach Mountains. Investigations by H. W. Coulter have revealed 8 such lakes, which imperil 5 bridges and 3 miles of highway. Relocation of bridges and realinement of parts of the road seem to be the best means of avoiding future disasters.

Harold D. Roberts tunnel

E. E. Wahlstrom, L. A. Warner, and C. S. Robinson (Art. 131) are correlating geologic features with engineering problems in the new Roberts water tunnel, which extends 23.3 miles under the Continental Divide near Denver, Colo. They have found that spalling rock which required heavy support is fresh, brittle, competent rock that occurs between bodies of weaker rocks or is bounded by faulted or fractured rock masses. Other areas requiring support are those passing through zones of layered rock, faults, joints, and clay alteration.

Subsidence

Subsidence of the land surface leads to various engineering problems whose solution requires an understanding of the geologic and hydrologic processes involved. During the course of studies of subsidence in the San Joaquin Valley, Calif., W. B. Bull (Art. 77) has found that near-surface subsidence on certain alluvial fans results chiefly from compaction of material by overburden as the clay bond in the sediments is weakened by water that percolates through them for the first time after their deposition.

Other findings in the study of subsidence are summarized under the heading, Effects of fluid withdrawal, beginning on page A–71.

Clays for canal lining

To aid in the search for low-cost canal lining material, B. N. Rolfe, R. F. Miller, and I. S. McQueen (1960) have studied the chemistry of the system—clay, water, ionized salt. They found that with the proper chemical dispersing agents, montmorillonite-type clays are relatively superior for penetrating and filling of small voids. On the other hand, kaolinite and illite clays, properly dispersed and allowed to settle from canal waters, may be suitable for filling joints, cracks, burrows, and other relatively large openings.

Measurement of displacement during hydraulic fracturing of rock

In tests of the feasibility of fracturing shale underground by hydraulic methods in order to obtain space for the storage of atomic wastes, a liquid-level tiltmeter described by F. S. Riley (Art. 136) has been found capable of measuring significant tilting at distances as far as 243 feet from the injection well. This method of measurement may have useful application in controlling grouting for ordinary construction purposes.

ENGINEERING PROBLEMS RELATED TO ROCK FAILURE

Landslides

In the Pacific Palisades area of Los Angeles, detailed mapping by J. T. McGill has revealed the relation of landslide distribution to geologically recent tectonic activity. Differential uplift of the major late Pleistocene marine terrace has caused faulting and warping of the wave-abraded bedrock platform and its veneer of marine and nonmarine sediments. Movement of ground water within the sediments is controlled primarily by the slope of the platform. Seepages and associated landslides tend to occur where the bedrock platform is inclined outward from canyon walls and sea cliffs.

The relation between landsliding and steep slopes that result from tectonic activity is illustrated by slides at the eastern base of the Funeral Mountains, Calif., described by C. S. Denny (Art. 323), and by slides along the Uinta fault in Utah described by W. H. Hansen (Art. 132). The slides along the Uinta faultline scarp are abundant where the northerly exposure minimizes insolation, and where moisture accumulates.

Many landslides, some of them exceptionally large, have been mapped in Puerto Rico. In the southern part of the island, very large debris slides described by P. H. Mattson have moved along a bedding plane of granular breccia. In north-central Puerto Rico, numerous slides occur at places where thick limestone units are underlain by beds of clay; one such slide involves more than 43 million cubic meters, or about 100 million tons of rock. Movement and growth of individual slides is continuous, but the toes tend to move so slowly that houses and roads are reasonably stable.

Further studies of the Slumgullion earthflow in southwest Colorado by D. R. Crandell and D. J. Varnes (Art. 57) have shown that the active part is moving at a rate of 20 feet per year in midsection to 2.5 feet per year at the toe. Comparison of aerial photographs made in 1939 and succeeding years together with direct measurements since 1958 indicate that the rate of movement has been essentially uniform for 20 years.

Rock mechanics as related to mining engineering

In studies of coal mine bumps, F. W. Osterwald (Art. 274) has found that most of the local deformational features in the Sunnyside No. 1 coal mine, Carbon County, Utah, are the result of lateral rather than vertical compression. Detailed mapping of the deformed rock, coal, and supports indicates the local distribution of compressive and tensional stress and aid in design of roof-control measures.

EROSION

Measurements by R. F. Hadley (Art. 16) in drainage basins in the High Plains have shown that northerly facing slopes are generally steeper, less dissected, and support a denser vegetation cover than southerly facing slopes, owing to differences in insolation, rate of melting of snow, and evaporation. Erosion is more rapid on southerly facing slopes, and the resultant debris displaces the main channel southward from the central axis of the basin. Other studies of land-form analysis (Schumm and Hadley, 1961) may apply to erosion problems throughout the semiarid parts of western United States.

G. C. Lusby (Art. 59) has found that runoff and sediment yield from grazed watersheds have been as much as twice that from similar ungrazed watersheds at Badger Wash, western Colorado. The sediment is apparently derived in large part from the deepening and widening of gullies rather than from the hillsides.

I. S. McQueen (Art. 14) has made a laboratory investigation of the physical properties of soil material that may influence erodibility. He has shown that, in general, a poorly sorted sediment with a small median grain size will resist erosion by water flowing at 1.2 feet per second better than a well-sorted sediment with a larger median grain size. The effect of grain-size distribution is, however, less important than factors related to packing, such as bulk density, structure, texture, cementation, porosity, and pore-size distribution, and the past history of wetting and drying. Samples that were dry-packed and then wetted to field capacity water content eroded from 2 to 400 times as fast as samples of the same material at approximately the same water content but which had previously been puddled.

C. A. Kaye's continuing study of the erosion at Gay Head, Martha's Vineyard, Mass., indicates that the cliff headland has probably receded about 4,000 feet in the past 3,000 years. The average retreat of the north end of this scenic exposure has been 1.8 feet per year during the last 75 years. Remedial measures that might be applied include drainage of swamps and depressions behind the cliff, dewatering by wells, and local protection of the cliff base by riprap (Kaye, 1961).

R. P. Briggs (1961) has found that rapid and destructive shoreline changes at Puerto Arecibo on the north coast of Puerto Rico are relatively recent phenomena. Field studies of the patterns of erosion and sedimentation and comparison of maps and aerial photographs covering the period 1791–1959 have shown that the shoreline was generally stable until 1940. A breakwater was constructed in the period 1940–42 in order to form a protected harbor. Most other factors have been essentially the same from at least the latter part of the 19th century until the present. Hence, the breakwater and dredging in the harbor appear to have caused the shoreline modifications by altering the systems of waves and currents.

Kenneth Segerstrom (1960a and Art. 370) has observed the erosion of ash at Parícutin volcano, Michoacán, Mexico, periodically from 1946 to December 1960. He found that by 1957 the rate of stripping of the ash mantle had decreased markedly, owing largely to increasing vegetation cover. Observations in 1960 indicated continued deceleration of erosion and redeposition because the most vulnerable ash deposits had been stripped off the steeper slopes and from the main stream channels. Areas covered by ash or ash reworked by streams are now being rapidly covered by increasing numbers and varieties of trees, shrubs, and small plants.

SELECTION OF SITES FOR POSSIBLE NUCLEAR TESTS AND EVALUATION OF EFFECTS OF UNDERGROUND EXPLOSIONS

Sites for possible underground and cratering nuclear explosions have been selected by the Atomic Energy Commission partly on the basis of studies by the Geological Survey. In addition to defining the geologic environment of possible sites, these studies have dealt with such problems as subsurface and surface water contamination by fission products, the containment and cratering of explosions, and the effect of structure and lithology on seismic energy distribution (Eckel, 1960a).

Nevada Test Site

The Nevada Test Site is the testing facility of the Atomic Energy Commission where performance of nuclear explosives has been studied during past test operations and where experimental nuclear reactors are being studied. The Survey advises the Commission on the geological aspects of its operations and has continued both general studies of the test site and special studies of the geologic and hydrologic effects of contained and cratering explosions.

Deep drilling to determine the occurrence, rate, and direction of movement of ground water beneath Yucca Flat continued in 1961; the water table or piezometric surface is 1,500 to 1,800 feet below the earth's surface, and the altitude of water levels in wells indicates very low hydraulic gradients. Ground water moves through Paleozoic bedrock, tuff of the Oak Spring formation of Tertiary age, and Quaternary alluvium. In both Frenchman and Yucca Valleys the observed water-level altitude is lowest in the deepest well, suggesting a decrease in pressure head with depth and an important downward component of water movement.

Although data are inadequate to estimate average rates and directions of ground-water movement, the tritium content of well water beneath Yucca and Frenchman Valleys and Jackass Flats as determined by Alfred Clebsch (Art. 194) indicates that the water in these basins has been underground 50 years or more. In marked contrast, tritium analyses of samples collected in August and September 1958, from the perched aquifer in Rainier Mesa and from the aquifer that discharges at Whiterock Spring indicate that the water in these upland parts of the test site entered the ground since November 1952 and before January 1958.

Chemical and radiochemical analyses of water samples obtained near the Logan and Blanca nuclear detonations of October 1958 showed the highest fission product content in the perched ground water within a few hundred feet of the blast points (Clebsch and Barker, 1960). Evidence of contamination was noted half a mile from the blast points, but samples 500 to 2,000 feet from the blast sites were not contaminated. Samples collected at points about 600 and 500 feet from the Logan and Blanca blast points, respectively, showed contamination in March 1959 but almost none in January 1960. Clebsch (1960) has concluded tentatively that the apparently erratic distribution of anomalous radioactivity in the perched water table resulted from expulsion of radioactive material along blast-produced fractures.

Recent study of wells in the Nevada Test Site by J. E. Moore has shown that the altitude of the permanent water table in the major basins within the Nevada Test Site—Yucca and Frenchman Valleys and Jackass Flat—ranges from 2,386 to 2,553 feet above sea level but averages 2,400 feet for the three basins. The water table altitudes in the basins to the north, east, and west, however, are 1,500 to 2,200 feet higher. It is inferred, from these data, that the natural discharge areas are southwest of the test site. There are two main sources of water at the Nevada Test Site. One of these includes the Oak Spring formation, of Tertiary age, and the younger alluvial fill. The other consists of the carbonate rocks, shales, and quartzites of Paleozoic age. Chemical analysis of samples from both sources shows that the waters contain from 282 to 476 parts per million total dissolved solids. The net extractable alpha and Sr^{90} in water samples range from >0.1 to 6.8 $\mu\mu c/1$ and $<.6$ to 2.0 $\mu\mu c/1$, respectively. J. W. Hood has demonstrated by aquifer tests that stored ground water in Frenchman and Yucca Flats will be adequate for many years at present pumping rates.

As a result of geologic mapping and gravity surveys, the limits have been defined for a collapsed caldera 6 to 7 miles in diameter, in the western part of the Nevada Test Site. The caldera is the assumed source of the widespread, thick welded-tuff sheets that make up the Oak Spring formation. Preliminary nomenclature for these volcanic rocks has been established by E. N. Hinrichs and P. P. Orkild (Art. 327). Large volumes of flow-banded rhyolite and basalt derived from vents along the peripheral fracture occur in the central part of the caldera. Locally extensive alteration of the volcanics along the fracture suggests near-surface intrusive masses.

Complex zeolites that make up as much as 45 percent by volume of the tuff of the Oak Spring formation have been described by A. O. Shepard. (See p. A–72.)

A prerequisite for evaluation of seismic signals generated by a planned underground nuclear explosion in the Climax granitic stock, in the northern part of the Nevada Test Site, is an accurate picture of the size, shape, and geologic setting of the stock. From aeromagnetic data, Isidore Zietz and J. W. Allingham have shown that the stock is circular, has an approximate diameter of 4 miles at sea level (about 5,000 feet below the surface outcrop), and has a minimum thickness of 15,000 feet. Geologic mapping by F. N. Houser and F. G. Poole (Art. 73) and zircon age determinations have shown that the stock is composite, and was intruded during Permian to early Mesozoic time.

D. D. Dickey and R. B. Johnson (Art. 278) have shown that the long dimensions of the high-explosive craters in basalt roughly parallel the strikes of prominent, nearly vertical joints. The long, narrow areas of ejecta beyond the rims of the craters, however, are oriented nearly normal to the direction of these joints. Ejecta are sparse in the directions parallel to these natural joints. An adequate knowledge of the distribution and orientation of natural fractures may be an economically important factor in the utility of cratering explosions for industrial purposes.

Plowshare program

As part of the Atomic Energy Commission's Plowshare program to develop peaceful uses for nuclear explosives, Project Gnome, near Carlsbad, Eddy County, N. Mex., is a proposed experiment to determine whether thermal energy and valuable isotopes can be recovered from a nuclear explosion completely contained within a homogeneous salt mass. A geologic and hydrologic study of the area by J. B. Cooper (1960) has revealed that the salt mass is overlain by a single confined aquifer, the Culebra dolomite member of the Rustler formation, which is 518 to 550 feet below the surface and 150 feet above the salt sequence. The Culebra has a transmissibility of 4,000 gpd/ft (gallons per day per foot).

ANALYSIS OF HYDROLOGIC DATA

Almost all hydraulic and hydrologic studies provide data that require interpretation and analysis, and many examples of such analysis have been summarized under other headings. Reported here are a few findings in each of several fields of research in which the results required new methods of analysis or very extensive analysis of large amounts of data.

FLOODS

A method of determining the probable magnitude and frequency of floods at any specific site in a defined region has been presented by Tate Dalrymple (1960). The method requires use of two diagrams, one in which the ratio of peak discharge to mean annual flood is related to recurrence interval, and the other in which the mean annual flood is related to size of drainage area and—for some areas—to other significant basin characteristics. From these two areal relations the relation between peak discharge and frequency of occurrence can be determined for a specific site.

The size of the mean annual flood is generally related directly to the size of the drainage area. Other factors of local significance and the region where they are most applicable are as follows: (a) elevation of drainage basin (eastern Montana, Wyoming, Utah, and the Colorado River basin), (b) area of lakes and ponds (Florida, Minnesota, Wisconsin, Pacific Northwest, Delaware River basin), (c) mean annual runoff (Kansas, Pacific Northwest), (d) geographical factor (Wisconsin, Pacific Northwest), and (e) lag factor (Illinois).

In a study of flood-plain planning, S. W. Wiitala, K. R. Jetter, and A. J. Sommerville have presented a method of estimating probable flood risk by use of existing data on flood magnitude and frequency, stage discharge relations, and flood profiles. They outline a method of preparing inundation maps for floods of several magnitudes and frequencies for three stated positions: (a) near a gaging station, (b) at a considerable distance from a gaging station, and (c) on an ungaged stream.

A summary of findings concerning the great flood of September 6, 1960, in Puerto Rico is presented on page A–47.

GROUND WATER

Studies by R. W. Stallman (1960) of the differential equation of simultaneous heat and water flow through an isotropic and homogeneous aquifer indicate that under natural conditions the direction and velocity of ground-water flow can be calculated for most aquifer systems, given only the temperature distribution in the aquifer.

In a study of glacial-outwash aquifers near Worthington, southwestern Minnesota, Robert Schneider (1961) used temperature fluctuations of ground water to estimate the rate of movement of water from Okabena Lake to nearby wells and to detect the infiltration of summer rainfall. Rates of movement ranged from about 2 to 6 feet per day under the prevailing gradients.

INTERRELATION BETWEEN SURFACE WATER AND GROUND WATER

The movements of surface water and ground water are so closely related that alteration of one soon affects the other. Techniques employed to study the relation include analysis of ground-water hydrographs and contour maps; correlations of ground-water levels and surface-water stage or discharge; basin-water budgets; use of steady-state analog models, non-steady-state electronic computers, and mathematical models; graphical statistical analysis; and use of temperature or chemical constituents as tracers.

Interchange of surface water and ground water under natural conditions

Seepage rates along the lower reaches of 21 streams tributary to the Sacramento and lower San Joaquin Rivers, Calif., have been reported by S. E. Rantz and Donald Richardson (Art. 215). Most of the streams intermittently lose water to, or receive water from, the underlying aquifer. The annual runoff of the streams on the west side of the San Joaquin Valley is 60,000 acre-feet, of which 60 to 80 percent reaches the ground-water body.

Response of ground-water levels to the annual flood cycle of the Columbia River in the 50-mile reach between China Bar and Richland, Wash., provides a basis for evaluation of bank storage. R. C. Newcomb found that the ground-water rise, when evaluated with the effective porosity, placed in bank storage an average of 170,000 acre-feet of water during the river's annual rise to flood peak. The stored water returns to the river during ebb flow in the succeeding 165 days.

In studies of the Walla Walla River basin, Washington and Oregon, R. C. Newcomb found that one-third of the 42 inches of annual precipitation on the mountainous watershed in the Blue Mountains infiltrates to the basalt and reaches the water table. The outflow to the South Fork and to Mill Creek provides the base flows of 150 cubic feet per second. These base flows are the main water supply of the basin during the dry summer months.

Induced infiltration of surface water

In a study of the hydrology of Wharton Tract, N.J., E. C. Rhodehamel and S. M. Lang have shown by means of water-level contours of pumping-test data that the connection between an underlying aquifer and the Mullica River is poor. An almost impervious layer of iron oxide in the stream bed is responsible.

Effect of withdrawal of ground water on streamflow

As part of studies of the geology and ground water of the Frenchman Creek basin above Palisade, Nebr., W. D. E. Cardwell and E. D. Jenkins made a long-range estimate of future irrigation withdrawals from wells and evaluated the effects on surface water. It was concluded that the point of effluence of Frenchman Creek would shift downstream about 5 miles and that the annual flow of Frenchman Creek into Enders reservoir would be reduced by about 17,000 acre-feet. If the projected irrigation developments materialize, the combined flow of Stinking Water and Frenchman Creeks near Palisade would decrease from 98,000 acre-feet in 1952 to about 80,000 acre-feet in the year 2008.

In a study of the Sevier Valley, Utah, between Sevier and Sigurd, R. A. Young and C. H. Carpenter determined by water-budget methods that an observed decrease of 20,000 acre-feet in streamflow is accompanied by additions to the ground-water level equivalent to a rise of one foot. This relation has been used to estimate the amount of ground water that may be pumped without seriously affecting streamflow.

Effect of impoundment on ground-water flow

In 1958, the St. Lawrence River in the vicinity of Massena, N.Y., and Cornwall, Ontario, was impounded for the generation of electric power. The rise in river stage amounted to about 80 feet at the Moses-Saunders Power Dam and about 20 feet at Waddington, 25 miles upstream. Through a wide area north of Massena the movement of ground water in the Beekmantown dolomite, the only extensive aquifer in the area, was reversed. Instead of flowing in a northerly direction toward the St. Lawrence it began to flow in a southerly direction toward the Grass River, which parallels the St. Lawrence at a distance of about 3 miles. Throughout most of the remainder of the area near the reservoir, ground-water levels were raised but the direction of ground-water flow was not reversed. Areas of artesian flow were developed in some low areas near the river.

A network of drainage canals in the Fort Lauderdale area, Florida, serves also as a source of recharge of fresh water to the very permeable Biscayne aquifer. The recharge is very important in helping to maintain the position of the salt-water front. An electrical analog steady-state model of the area is being used by C. B. Sherwood to determine the most suitable water levels for the various canals during low water. Boundary conditions and trial potentials that simulate canal stage are imposed on the model; the resulting ground-water potentials are then mapped. The amount of fresh-water flow to the ocean is computed and the position of the salt-water front is estimated from the water-level map.

LOW FLOWS

Data processing by a high-speed digital computer has made practicable the determination of annual values of the lowest mean discharge of streams for periods of various lengths. Low-flow frequency curves, which are useful in project design, can thus be prepared quickly and easily.

The Geological Survey has processed more than 50,000 station years of streamflow record and the work is continuing. Products obtained thus far include (a) annual values of the lowest mean discharge for 11 periods ranging in length from 1 to 274 consecutive days, (b) annual values of the highest mean discharge for each of the 11 periods, and (c) values from which a duration curve for each station can be readily prepared.

A low-flow frequency curve for each of the 11 periods at selected long-record stations in 10 eastern states is now available. These curves may be used to determine the dependable low-flow yield at the site, both without and with artificial storage.

TIME OF TRAVEL OF WATER

Industries along rivers create pollution problems and hazards. One hazard is the possibility of accidental release of dangerous contaminants upstream from points of withdrawal for water supply. Estimates of flow velocity and time of travel of contaminated water can be made from standard streamflow data.

A study of the flow of water in the Potomac River recently completed by J. K. Searcy and L. C. Davis, Jr., (1961) indicates a 50-percent chance that the travel time of water from Cumberland, Md., to Washington, D.C., is at least 110 hours in March and 345 hours in October. More specific estimates can be made by using the stage of the river on the day of the estimate. The estimate is based on velocities in cross-sectional areas at stream-gaging stations, and on correlation of concurrent discharge at upstream and downstream points.

A companion study of the Ohio River by R. E. Steacy (1961) indicates that when the river discharge at Cincinnati is 60,000 cubic feet per second (the median daily discharge), travel time of water from Pittsburgh is 360 hours under average conditions. When the discharge is less than 30,000 cubic feet per second, as it generally is in August, September, and October, travel time is more than 600 hours.

EVAPORATION SUPPRESSION

In tests of methods for suppressing evaporation, R. R. Cruse and G. E. Harbeck, Jr. (1960) have examined 150 film-forming materials, all of which were found to be ineffectual at economic concentrations. A maximum reduction in evaporation of 18 percent was obtained with hexadecanol.

ARTIFICIAL RECHARGE OF AQUIFERS

In many parts of the United States the prolonged withdrawal of ground water from wells has resulted in a lowering of the head and a decrease in the quantity of water available. Studies to determine the feasibility of artificially recharging underground reservoirs with surplus surface waters have been made in several selected areas by the Geological Survey. These studies have included recharge by spreading basins, by stream channel diversion and enlargement, and by injection wells.

Spreading basins

Recent studies by C. R. Groot (1960) near the well field of Newark, Del., show that when surface water is spread over the well field, infiltration takes place at a rate of 3 feet per day. This amount adds significantly to the ground-water reservoir.

Stream channel diversion

Tests by Morris Deutsch and J. E. Reed have shown that the aquifer supplying water to Kalamazoo, Mich., can be partly recharged with surface water by diverting a local stream and causing it to flow in a man-made channel across the well field.

Yield deterioration in injection wells

The performance of injection wells in basalt near Walla Walla, Wash., has been tested by R. H. Russell (1960), and the performance of wells in alluvium in the Grand Prairie region of Arkansas has been tested by R. T. Sniegocki, F. H. Bayley, III, and Kyle Engler. Partial clogging of the wells in both areas took place within 2 or 3 weeks. The clogging is believed to result from (a) sediment and dissolved air in the injected water, (b) precipitation of iron in the injected water as a result of aeration, and (c) micro-organisms in the injected water.

GEOLOGY AND HYDROLOGY APPLIED TO PROBLEMS IN THE FIELD OF PUBLIC HEALTH

Urbanization and industrialization have caused increasing concern with problems of public health and safety. Many research studies of the Geological Survey result in benefits in this field. Studies in 1961 directly concerned with public health include work on the disposal of radioactive wastes, the distribution of elements in relation to health, and studies of coal-mine drainage in the eastern United States.

STUDIES RELATED TO DISPOSAL OF RADIOACTIVE WASTES

Studies bearing on radioactive waste storage or disposal are conducted on behalf of the Atomic Energy Commission and deal with actual and potential behavior of high-, intermediate-, and low-level wastes in specific geologic environments, and with the natural processes by which contaminants in surface and ground water are neutralized or dissipated.

E. S. Simpson has shown that dispersion coefficients in natural streams are related to variables of stream flow that are relatively easy to measure. His studies bear directly on the mixing and dilution of radioactive and other wastes in streams.

D. H. Hubbell is studying the extent to which radioactive material may be accumulated and concentrated in stream sediments. Tracer particles were released as an instantaneous line source in the stream channel of the North Loup River near Purdum, Nebr. The concentration of particles in the stream bed were found to be a logarithmic function of the distance along the channel, and the standard deviation of the distribution increased in proportion to the time after release. The highest concentration of particles moves downstream at a velocity about equal to the velocity of the dunes that represent the form of bed roughness.

H. E. Skibitzke and others (1961c) have studied the flow of water in a saturated porous aquifer through use of radioactive tracers. They have found that as the water and tracers move longitudinally through the aquifer, the rate of lateral spreading of the tracers is slightly less than the rate of spreading that would be produced by molecular diffusion in a motionless liquid.

Preliminary analyses of the Michigan Basin have been made by Wallace DeWitt, Jr., and of the Appalachian Basin by G. W. Colton to determine the possibilities for radioactive-waste disposal. Colton concludes that in the Appalachian Basin, evaporites of the Salina group and sandstone, shale, and mudstone of the Bloomsburg red beds provide the safest natural reservoirs for storage, and that the Devonian black shales may be suitable for waste storage is artificially fractured reservoirs.

DISTRIBUTION OF ELEMENTS AS RELATED TO HEALTH

The increasing understanding of the importance of trace elements to the health and nutrition of both animals and humans has led to a desire for an appraisal of their mode of occurrence and degree of availability in soils of the United States.

As a part of an environmental study being made on the occurrence of cancer, R. M. Moxham reports that the natural background radioactivity in Washington County, Md., varies according to a geologically controlled pattern, and that the more radioactive zones are associated with shale or with the shaly parts of limestone units. The amount of radiation is controlled largely by potassium, which is enriched in the residual clays. The surface radioactivity in Washington County varies by as much as a factor of 5, but more commonly by a factor of 2 to 3.

The trace-metal composition of soils and plants has been studied by H. L. Cannon in two widely separated areas of abnormal cancer occurrence: glacial soils overlying the Hamilton shale at Canandaigua, N. Y., and residual and alluvial soils on the Cambrian and Ordovician rocks in Washington County, Md. In both areas the content of total lead, copper, boron, and zinc in the soils is considerably above average, and that of manganese and iron is about normal. The availability of most of these elements to plants is, on the other hand, very low. The content of copper, zinc, molybdenum, and boron, and to an even greater degree, manganese and iron, are deficient in the garden vegetables as compared to the averages for herbs.

Samples of vegetables collected within 25 feet of roads in Washington County, Md., contained an average of 80 ppm (parts per million) lead in the ash, or about 4 times that of vegetables grown at distances of more than 500 feet from roads. In the Denver, Colo., area, pasture grass within 5 feet of major highways contains as much as 700 ppm lead in the ash, and grass at major intersections contains as much as 3,000 ppm in the ash. These data invite speculation on the possible toxic effects of this cumulative poison in garden produce, particularly that grown near major highways.

About 90,000 traverse miles have been flown during the past year by the Geological Survey as part of the nationwide program of aerial radiological monitoring surveys (ARMS) of the Atomic Energy Commission. These surveys provide essential data on environmental background radiation for evaluating the effects of radiation on health. The radioactivity data are also valuable in supplementing geologic mapping in areas of heterogeneous rock types, thick residual soils, and low topographic relief.

MINE DRAINAGE

In connection with studies of drainage of anthracite mines in Pennsylvania, W. T. Stuart and T. A. Simpson (Art. 37) noted that the pH of the water in certain flooded mines decreased with depth below the pool surface. In one mine the pH near the pool surface was 7.1 and near the bottom of the shaft it was 4.1. Where pool water was mixed by pumping, by overflow into drainage tunnels, or by some other cause, no significant layering of acid water was observed. Knowledge of the distribution of the acid facilitates pollution control and may reduce the cost of pumping and handling.

DEVELOPMENT OF EXPLORATION AND MAPPING TECHNIQUES

In addition to conventional methods of exploration that depend primarily on mapping bedrock exposures and on examining samples from drill holes, much work is being done in the newer fields of geochemical and botanical exploration, and in the use of isotopes as clues to the distribution of mineral deposits. New equipment is being developed and old equipment modified to measure and record geologic and hydrologic data.

GEOCHEMICAL AND BOTANICAL EXPLORATION

F. C. Canney and A. L. Albee have discovered two major geochemical copper anomalies on Sally Mountain in the Attean quadrangle, Somerset County, Maine. This area also contains iron-stained, pyritized, and hydrothermally altered rock, and hence appears to have above average mineral-resource potential.

In Aroostook County, Maine, anomalous amounts of molybdenum in soil samples may be used to locate molybdenum deposits beneath a thin cover of glacial drift. F. C. Canney, F. N. Ward, and M. J. Bright, Jr., (Art. 117) report one anomaly in this area in which molybdenum occurs in concentrations 90 times the regional background.

Studies by L. C. Huff and A. P. Marranzino (Art. 133) in the vicinity of alluvium-buried copper deposits in the Pima mining district of Arizona indicate that systematic analysis of ground water, phreatophytic plants, and carbonate-cemented zones at the base of the alluvium may yield data useful in searching for buried ore. Huff and Marranzino report anomalous amounts of molybdenum in ground water for at least 10 miles northeast (downslope) from the Pima and Mission ore bodies.

Using the Geological Survey's mobile spectrographic laboratory, R. L. Erickson and others (Art. 401) have discovered a geochemical anomaly in the upper plate of the Roberts Mountain thrust fault, Nevada, that may prove to be a leakage halo from concealed ore deposits in the thrust zone or in the carbonate rocks beneath the thrust.

In the Red Mountain area of Clear Creek County, Colo., P. K. Theobald, Jr., and C. E. Thompson (Art. 58) have found anomalous concentrations of several metals in large areas covered by poorly consolidated surface rubble. The patterns of the anomalies suggest early deposition of tungsten and molybdenum, accompanied by removal of zinc and copper, and followed by deposition of lead and arsenic, and of minor amounts of zinc and copper.

Botanical methods of prospecting for uranium on the Colorado Plateau have been described by Helen L. Cannon (1960b). Chemical differences in the rocks in mineralized areas produce recognizable changes in plant societies. Some plant species, therefore, are useful as indicators in prospecting. Other plants are useful in prospecting by plant analysis because they absorb increased amounts of uranium in uranium-rich areas. Chromatographic field tests have been devised to facilitate the rapid analysis of plant samples.

R. W. Bayley and W. W. Janes (Art. 405) report on analysis of soils in the Atlantic gold district, Wyoming, and suggest that anomalous concentrations of arsenic may indicate hidden quartz-arsenopyrite-gold veins.

Conventional methods of prospecting are hindered by heavy vegetation and thick soil cover in the Coeur d'Alene district, Idaho. V. C. Kennedy (1960a) describes soil-sampling techniques in this district and gives information on the dispersion of ore metals. Kennedy concludes that lead is the best indicator element in prospecting for ore bodies rich in lead and zinc.

Botanical studies by H. T. Shacklette (1961) on Latouche Island, Alaska, have shown a close correlation of the metal content of the substrate with the composition of moss communities and with the succession of moss species.

APPLICATION OF ISOTOPE GEOLOGY TO EXPLORATION

The isotopic compositions of several elements are found to have large differences that can be related to origin and distribution of ores and rocks. Some of the more general applications, such as those in geochronology, are presented on pages A-80 to A-81; those that bear more directly on problems of ore deposits are discussed below.

Isotope geology of lead

A general review of the isotope geology of lead with particular reference to its application in the study of and search for ore deposits has been published by R. S. Cannon and others (1961). Further work by these men, in collaboration with S. W. Hobbs, V. C. Fryklund, and L. R. Stieff, has shown that, in general, the leads in the major ore deposits of the northern Rockies region (Coeur d'Alene, Idaho, and East Kimberley, British Columbia) have similar isotopic compositions, whereas those in minor deposits have divergent compositions. On a smaller scale, it is found that within the Coeur d'Alene district similar compositional differences exist between the larger and smaller ore bodies. In part, these differences may be related to stratigraphy of the Precambrian sedimentary rocks—the principal ore bodies of the Coeur d'Alene and East Kimberley districts are in the Prichard formation and its correlative, the Aldridge formation, whereas many of the minor deposits are in the calcareous Wallace formation and equivalents.

Oxygen isotopes in mining districts of central United States

The variations in isotopic composition of oxygen in the carbonate host rocks of the lead-zinc ore deposits of the Upper Mississippi Valley and of the fluorite deposits of Kentucky and Illinois are being investigated by W. E. Hall, Irving Friedman, and A. V. Heyl, Jr. At the Dyer Hill fluorite mine, Kentucky, the O^{18}/O^{16} ratio of the limestone (as determined by mass spectrometer and expressed in the standard permil units) changes within 40 feet from a normal limestone value of 24 ‰ to 16 ‰ as the ore is approached. The isotopic alteration of the wall rock by ore-forming solutions is in part dependent upon grain size; coarse-grained pre-ore calcite is less susceptible to change than is the finer grained limestone.

The "falling drop" method of oxygen isotope analysis

J. H. McCarthy, Sr., T. S. Lovering, and H. W. Lakin (Art. 292) have completed work on the "falling-drop" method for determination of oxygen isotope ratios of carbonate rocks. The technique is designed to afford a rapid and inexpensive means of obtaining oxygen isotope data for geochemical exploration; during the year the apparatus and procedures have been simplified to allow operation by nontechnically trained personnel.

RECORDING GEOLOGIC INFORMATION

Magnifying single-prism stereoscope

A magnifying single-prism stereoscope designed by T. P. Thayer (Art. 426) for field use holds the photographs firmly in place, provides magnifications up to 2 diameters, and covers the entire stereoscopic model. The stereoscope is 1½ inches thick when folded, and weighs about 3 pounds.

New method of recording geologic features

E. H. Baltz and J. E. Weir, Jr., (Art. 137) have found that by constructing to scale a core diagram of large-diameter drill holes they can obtain quickly a true three-dimensional model of the rocks penetrated. The core diagrams can be used to determine strike and dip graphically or trigonometrically and to record graphically features observed on the walls of large-diameter drill holes.

HYDROLOGIC MEASUREMENTS

The scope of the Geological Survey's hydrologic program is largely dependent upon the speed and accuracy of gathering data. As a result, measuring and recording devices are undergoing constant improvement. Several new instruments were put into use in 1961 as described below.

Digital recorders and computer techniques

A new technique for automatic recording and processing basic streamflow data, developed by W. L. Isherwood, makes use of a slow-speed battery-operated paper-tape punch at gaging stations and a general-purpose digital computer in Washington, D.C. The field recorder samples a shaft-rotation input at intervals of 15, 30, or 60 minutes and punches each reading of river gage height as 4 binary-coded decimal digits in parallel mode on 16-channel paper tape. At the central processing center the 16-channel tape is translated to 7-channel serial-coded paper tape suitable for computer entry so that the data can be edited by the computer and stored on magnetic tape. Stage-discharge rating tables needed for the computation of discharge are manually punched on paper tape. The computer produces 3 items of output as follows: (a) a printed form listing the daily mean gage heights, shift corrections, and daily mean discharges; (b) a set of IBM cards containing information on peak discharges to be listed off-line; (c) a set of IBM cards containing logarithmic plotting positions for use on an off-line automatic plotter.

Recorders are installed on a trial basis at 260 of the Geological Survey's nationwide network of more than 7,000 gaging stations.

Velocity-measuring instruments

Three new instruments for measuring water velocity in open channels are being developed. The acoustic velocity meter (H. O. Wires, Art. 27) uses ultrasonic waves for the continuous recording of the mean integrated velocity on a horizontal line within a stream cross section. The optical current meter (Winchell Smith, Art. 424) uses a system of rotating mirrors and a stroboscope to measure surface velocity. The electromagnetic velocity meter, a modification of U.S. Navy's ship log, continuously records the velocity of water flowing past a fixed probe in the stream. Water moving through the magnetic field set up by an exciter coil in the probe generates a voltage that is proportional to the water velocity.

Stage-measuring instruments

The surface follower, designed by G. F. Smoot, will follow the rise and fall of a liquid surface in a vertical 2-inch pipe. A battery-powered reversible motor raises or lowers a float-switch assembly in response to changes in elevation of the liquid surface.

E. G. Barron and H. O. Wires have designed a two-speed timer that automatically expands the time scale of a continuous water-stage recorder by a multiple of six during stages above a selected base. A solenoid-ratchet device advances the recorder paper 1/80 inch each time it receives an electrical impulse. Two sets of cams and contacts on the spring-driven clock provide either 8 or 48 pulses per hour. A selector switch can be set to change from the 8 pulse per hour contacts (2.4 inches per day) to the 48 pulse per hour contacts (14.4 inches per day) at the selected stage.

Velocity-azimuth-depth assembly

The velocity-azimuth-depth assembly, developed by E. G. Barron, H. O. Wires, and G. F. Smoot, measures the velocity and direction of flow of water and the height above the bottom at any point in a stream. Velocity is measured with a Price current meter, direction of flow is given by a remote-indicating compass, and depth is measured by sonic means. The assembly is useful in investigations of tidal flows and of stream cross sections where the flow pattern may be complicated by variable eddy currents.

Well logging

Drill holes at the National Reactor Testing Station, Idaho, penetrate a sequence several hundred feet thick of interbedded basalt and clastic sedimentary rocks. P. H. Jones (Art. 420) finds that the diameter of the drill holes increases with the permeability of the rock, and that caliper logs are especially useful in identifying the aquifers and in determining their relative transmissibility.

ANALYTICAL AND OTHER LABORATORY TECHNIQUES

The analytical laboratories of the Geological Survey contribute many different kinds of data necessary for the conduct of geologic and hydrologic investigations, and for this reason much analytical information has been summarized under other headings. In particular, analytical data applicable to studies of isotopes are summarized on pages A–80 to A–82 and A–96, and data applicable to geochemical prospecting are summarized on pages A–95 to A–96.

In addition to providing factual data in support of other activities, the laboratories also independently investigate new methods of analysis and new techniques that will improve accuracy and efficiency. Some of the results of these investigations are summarized below.

ANALYTICAL CHEMISTRY

Rapid rock analysis

Rapid methods of analysis developed by Leonard Shapiro and W. W. Brannock [37] for silicate rocks have been revised and supplemented with methods for carbonate and phosphate rocks to form an integrated scheme for the complete analysis of the major rock types. Silicon, aluminum, total iron, titanium, phosphorus, manganese, and fluorine are determined spectrophotometrically; calcium, magnesium, and iron titrimetrically; sodium and potassium by flame photometry; water and sulfur gravimetrically; and carbon dioxide volumetrically.

Combined gravimetric and spectrographic analysis of silicates

Extensive revision has been made by R. E. Stevens in the wet chemical procedures used in spectrogravimetric analysis. A photometric method has been adopted for determining silica passing into the filtrate in the determination of silica. Small precipitates that have spread over the interior of a crucible cannot be collected readily for spectrographic analysis. Therefore, processes have been designed to keep such precipitates in the lump form obtained on ignition of a paper-filtered precipitate. For calcium and magnesium oxide separates, a simple

[37] Shapiro, Leonard, and Brannock, W. W., 1956, Rapid analysis of silicate rocks: U.S. Geol. Survey Bull. 1036–C.

apparatus has been devised in which the oxides are converted to sulfates with sulfur trioxide vapors, thus avoiding solution and dispersal of material. Small quantities of alkalies, left at the end of the analysis, are collected by scrubbing the crucible with a wet filter paper and igniting this below the melting point of the alkali sulfates. The alkalies are thus obtained as a lump, easily removed from the crucible.

Spectrophotometry

Mary H. Fletcher (1960a and b) has presented the results of her studies on the dye 2,2′,4′-trihydroxyazobenzene-5-sulfonic acid and its reaction with zirconium. Published data include 3 of the 4 ionization constants of the dye, the two equilibrium constants for its reaction with zirconium, the absorption spectra of the various ionization forms of the dye, and the spectra of the zirconium complexes. Methods are discussed for the interpretation of absorption spectra of multicomponent systems and for the determination of dye purity.

Flame photometry

Many elements interfere in flame photometric determinations by depressing the intensity of flame spectra. Preliminary results obtained by J. I. Dinnin (Art. 428) indicate that high concentrations of calcium, strontium, barium, or lanthanum completely release magnesium from the depressive effects of aluminum and phosphate in perchloric acid or acetone media. Strontium or calcium completely releases barium from the effects of aluminum and phosphate.

Dinnin (Art. 429) describes a procedure for determining strontium in which the depressive effects of aluminum, phosphate, and sulfate are completely eliminated by high concentrations of lanthanum, praseodymium or neodymium.

Two flame photometric methods for determining strontium in natural waters have been developed by C. A. Horr. Strontium can be determined directly in concentrations greater than 0.2 ppm when a potassium chloride-citrate radiation buffer is used. Strontium at concentrations as low as 0.02 ppm is determined by passing the sample through a strongly basic cation exchange resin and eluting with 2M ammonium acetate-1M acetic acid solution, adjusted to a pH of 5.4. Strontium is concentrated 10-fold by this procedure, and is determined by flame photometry in the eluate. Errors due to anionic interference and variations in anionic composition of samples are thereby avoided.

Sodium-sensitive glass electrodes

Sodium-sensitive glass electrodes are useful in clay titrations, although their emf values cannot be indiscriminately used to yield sodium activities. A. M. Pommer (Art. 284) has found that in a montmorillonite titration, the electrode gives low sodium activities at low sodium concentrations, possibly as a result of the formation of ion-pairs or $NaCO_3$.

Fatigue in scintillation counting

A study of the variation of the counting rates of radium solutions by F. J. Flanagan (Art. 139) indicates that the photomultiplier fatigue causing the variations is due primarily to bremstrahlung produced by the interaction of beta particles with the glass containers.

Silica in chromite and chrome ores

J. I. Dinnin (Art. 433) found that in the gravimetric determination of silica in chromite enough silica remains unrecovered even after a double dehydration to cause appreciable error in the silica value for a purified chromite. As much as 2 milligrams of silica is unrecovered from a 1-gram chromite sample containing 1 percent silica.

Ferrous iron

J. J. Fahey (Art. 291) has determined ferrous iron in samples of magnetite and ilmenite intergrown with amphiboles and pyroxenes by decomposing the oxide minerals with 1:1 hydrochloric acid and titrating the iron with permanganate. The decomposition procedure results in little or no solution of the ferrous iron silicates.

R. L. Meyrowitz has developed a new microprocedure for determining ferrous iron in small amounts (5 to 15 mg) of pure refractory silicate minerals, such as garnets that contain a large proportion of both ferrous iron and magnesium. The sample mixed with sodium metafluoborate is fused in a Pregl platinum microboat at approximately 850° to 900°C in an argon atmosphere. The melt is dissolved in a standard $H_2Cr_2O_7$ solution containing H_2SO_4 and HF. The excess dichromate is determined by titration with standard ferrous iron using sodium diphenylamine sulfonate as the indicator.

Indirect semiautomatic titration of alumina

An indirect semiautomatic determination of alumina with EDTA was developed by J. I. Dinnin and C. A. Kinser (Art. 142). The method involves a back-titration with ferric chloride of excess EDTA using tiron as an indicator. A sharp end point is obtained with a colorimetric recording titrator.

Chemical test for distinguishing among chromite, ilmenite, and magnetite

J. I. Dinnin and E. G. Williams (Art. 430) have described a test for distinguishing among chromite, ilmenite, and magnetite, based on the relative rates of dissolution of the minerals in a mixture of phosphoric and sulfuric acid and on the colors of the resultant acid solutions.

Beryllium by gamma-ray activation

Factors such as particle size, sample weight, and sample-container shape in the gamma-ray activation analysis method for beryllium were studied by Wayne Mountjoy and H. H. Lipp (Art. 287). Reliable results are obtained when large samples are counted in half-pint cylindrical paper cartons. For samples under 100 g, counting is best done in conical holders. Particle size has little effect on counts per gram of sample.

Trace-element sensitivities

F. S. Grimaldi and A. W. Helz (Art. 427) have compiled and evaluated trace-element sensitivities of wet chemical, spectrochemical, and activation methods of analysis.

Precipitation of selenium

A study of the completeness of precipitation of selenium with hydroxylamine was made by Irving May and Frank Cuttitta (Art. 431). Precipitation was found to be 99.9 percent complete for concentrations of more than 0.9 parts per million (ppm) selenium, 99.0 percent complete for concentrations of 0.09 ppm selenium, and 80 to 90 percent complete for concentrations of 0.009 ppm selenium.

Colorimetric iron determinations

Bathophenanthroline in a N,N′-dimethylformamide medium was used by Frank Cuttitta and J. J. Warr (Art. 289) in the determination of traces of iron in zircon. Zirconium was complexed with mesotartaric acid to prevent its precipitation as the hydrous oxide.

The reagent tiron was used by Leonard Shapiro and Martha S. Toulmin (Art. 141) for the colorimetric determination of iron in small samples of sphalerite. The method is simple and rapid and enables analyses to be made on individual crystal fragments as may be required in geothermometry studies of sphalerites.

Thallium in manganese ores

The dithizone mixed-color method has been used by Frank Cuttitta (Art. 290) to determine small amounts of thallium in manganese ores. The interference of manganese, iron, bismuth, lead, tin, and indium was overcome by extracting thallium bromide with ethyl ether.

Direct fluorescent procedure for beryllium

A procedure was developed by Irving May and F. S. Grimaldi for the direct determination of beryllium in low-grade ores and in rocks using the well known fluorescent morin method. This very sensitive procedure enables the determination of as little as 0.0002 percent beryllium in only a 0.5-mg aliquot of sample without the necessity of performing any separations.

Copper in plant ash

Neo-cuproine has been used for rapid determination of traces of copper in plant ash. Claude Huffman, Jr., and D. L. Skinner (Art. 143) obtained a standard deviation of 9.6 ppm for the range of 15 to 200 ppm copper.

SPECTROSCOPY

Development and use of the electron microprobe and analyzer

The electron microprobe analyzer,[38] which provides point by point analysis of elements in absolute amounts as small as 10^{-12} grams, has been modified to permit simultaneous determinations of 4 elements.

Using the electron microprobe, Isidore Adler and E. J. Dwornik (Art. 112) analyzed shreibersite (rhabdites), kamacite, and the associated oxides in a piece of the Canyon Diablo meteorite and found the nickel content of 9 rhabdites ranges from 22 to 48 percent; the average of 11 determinations for nickel and iron in kamacite is 7.3 and 89 percent, respectively; and the oxide phase having the nickel content contains from 1.4 to 3.1 percent nickel and 46 to 48 percent iron.

In another study, iron-titanium oxide minerals in grains from 5 to 10 microns in diameter were analyzed for iron and titanium for possible correlation with magnetic properties. It was possible to examine compositional zoning from 2 to 4 microns across in a 40 micron grain.

Spectrochemical analysis for beryllium with a direct-reading spectrograph

Beryllium was determined in samples from Alaska, Colorado, and Utah by a spectrochemical method described by A. W. Helz and C. S. Annell (Art. 288) in which selected spectral lines are measured directly with multiplier phototubes rather than on a photographic plate. The samples were prepared by fusion in lithium tetraborate, powdered, mixed with graphite, and pressed into pellets one-half inch in diameter. The pellets were used as the lower electrode of a sparklike discharge for the production of the spectrum. Beryllium was determined in concentrations as low as 0.0002 percent even though the dilution of the sample with lithium tetraborate and graphite was 27 times.

Spectrographic analysis of minor elements in natural water

A method for the quantitative determination of 24 common minor elements in residues of evaporated water has been reported by Joseph Haffty (1960). Part of the water residue is mixed with one-half its

[38] Synopsis of geologic results—Geological Survey research 1960: U.S. Geol. Survey Prof. Paper 440–A, p. A72–A73.

weight of pure graphite powder and the mixture completely volatilized in a d-c arc of 16 amp. Concentrations are determined directly from working curves prepared by arcing a series of standards containing known amounts of the elements in a matrix approximating the composition of the water residues being analyzed. The analytical range for most minor elements is 1.0 to 100 μg (micrograms) per liter.

W. D. Silvey has applied chemical enrichment techniques to the determination of 17 minor elements in waters of widely different composition. Three organic chelating agents, 8-hydroxyquinoline, thionalide, and tannic acid, are added to a liter or more of sample. These agents quantitatively precipitate the minor elements and separate them from the soluble major constituents. The ashed precipitate is mixed with pure graphite, the mixture transferred to cupped graphite electrodes, and excited in a d-c arc. An excess of indium is added as a radiation buffer and palladium added as an internal standard. The method permits quantitative determination of 1.0 to 100 μg per liter of each of the 17 elements. For certain elements, as little as 0.1 μg per liter can be determined.

A copper-spark procedure for determining the 5.0 to 1,000 μg per liter of strontium was developed by M. W. Skougstad. Measured volumes of a spectroscopic buffer solution and a lanthanum chloride solution (internal standard) are added to a 10-ml sample aliquot. One-tenth ml portions of this sample mixture are then evaporated on the flat ends of copper electrodes and subjected to a high-voltage spark discharge. The measured relative intensities of the strontium lines at 4077.7A and 4215.5A and the lanthanum lines at 3949.1A and 4077.3A are used to prepare working curves and for quantitative estimation of strontium concentrations.

Spectrochemical analysis for major constituents in natural water with a direct-reading spectrograph

Joseph Haffty and A. W. Helz (Art. 144) investigated direct-reading techniques for determining four major constituents in water. Samples and standards, after being mixed with a reference solution, are excited directly using the rotating disk method. From 1 to 316 ppm of sodium, 3 to 316 ppm of calcium, 0.3 to 100 ppm of magnesium, and 3 to 31.6 ppm of silica can be determined in a single sample in a few minutes.

MINERALOGIC AND PETROGRAPHIC TECHNIQUES

Microscopy

Determination of the optical properties of organic crystals with the universal stage is greatly handicapped by the strong birefringence and dispersion that characterize many organic compounds. R. E. Wilcox (1960) has pointed out that the difficulties are overcome with the spindle stage. Wilcox has also investigated the use of focal screening techniques in determining refractive indices of particles by the immersion method. These techniques take advantage of the generally strong difference in dispersion in ordinary white light between the solid and a matching immersion liquid. The dispersion produces color effects at the grain boundaries, depending upon the wave length at which the refractive indices of liquid and solid exactly match. Reliable determinations of refractive indices can be obtained by focal screening in many situations where the conventional Becke-line technique is difficult to apply, or fails altogether.

X-ray petrography

D. B. Tatlock (Art. 145) has shown that the relations among diffraction, adsorption, fluorescence, and rock density allow rapid and accurate quantitative measurements for total iron ($FeO+Fe_2O_3$) and quartz in most holocrystalline silicate rocks. Preliminary results show that K-feldspar, albite, muscovite, and andalusite may also be determined quantitatively in certain rock types.

E. D. Jackson (Art. 252) has found that X-ray diffraction methods for determining the An content of plagioclase feldspars may be used confidently on feldspars from the same intrusive bodies. He points out that the plagioclases from a single intrusion will have similar thermal histories, therefore, there is no problem of X-ray parameter variance resulting from comparison of plagioclases with different thermal histories.

X-ray methods

A. J. Gude 3d, and J. C. Hathaway have devised a method for mounting very small (less than 1 mg) samples on the X-ray diffractometer. The sample is supported by extremely thin collodion membranes, which contribute insignificant amounts of background scatter to the X-ray pattern. The membranes are made by spreading thin films of colodion on water and transferring them to a standard diffractometer holder. The method takes advantage of the greater diffractometer speed and ease of interpreting the charts compared with the slower powder camera and film technique.

E. C. T. Chao (1960a) has developed a viewing device that allows visualizing X-ray diffraction precession photographs in the third dimension. The three dimensional view of the reciprocal lattice simplifies the indexing of reflections, and systematic extinctions of reflections can be readily observed.

Staining techniques

W. R. Griffitts and L. E. Patten (Art. 286) have developed a method for determining the distribution of beryllium in rock specimens by partially dissolving the beryllium ore minerals on a cut slab and transferring the resulting pattern of dissolution to an activated filter paper. A morin solution on the filter paper is converted into a fluorescent beryllium-morin compound and the distribution of beryllium can be determined under ultraviolet light.

Analyses using heavy liquids

Robert Meyrowitz and others (1960) have extended their study of heavy liquid diluents and recommend that N, N-dimethyl formamide can be used as a diluent for methylene iodide. The N, N-dimethyl formamide-methylene iodide mixtures were found to be more color stable than the dimethyl sulfoxide-methylene iodide mixtures, though the latter are generally satisfactory. (See Cuttitta and others, 1960.)

R. G. Coleman has used dimethyl sulfoxide as a diluent for both bromoform and methylene iodide to prepare a density kit for field testing of rock chips. A series of stable liquids thus prepared covers a fairly broad density range and enables the geologist to estimate rock density on a semiquantitative basis in the field.

Bulk density determinations

C. M. Bunker and W. A. Bradley (Art. 134) have designed equipment for determining bulk density of drill-core samples by a nuclear irradiation technique involving gamma-ray absorption. Comparative data on a series of selected core samples show that the gamma-ray absorption method is much faster and has about the same accuracy as the standard laboratory methods for determining the bulk density of homogeneous core samples.

Sample preparation

T. C. Nichols, Jr., (Art. 140) describes a method of concentrating and preparing carbonate shells for C^{14} age determinations. Selective sieving, air elutriation, and cleaning with an ultrasonic transducer has simplified the separation of shell material and improved the quality of material for analysis.

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U.S. GEOLOGICAL SURVEY OFFICES

MAIN CENTERS

U.S. Geological Survey, Main Office, General Services Building, 18th and F Streets, N.W., Washington 25, D.C., Republic 7–1820.
U.S. Geological Survey, Rocky Mountain Center, Federal Center, Denver 25, Colorado, Belmont 3–3611.
U.S. Geological Survey, Pacific Coast Center, 345 Middlefield Road, Menlo Park, California, Davenport 5–6761.

GEOLOGIC DIVISION FIELD OFFICES IN THE UNITED STATES AND PUERTO RICO

[Temporary offices not included]

Location	*Geologist in charge and telephone number*	*Address*
Alaska, College	Troy L. Péwé (3263)	P.O. Box 4004; Brooks Memorial Building.
Arizona, Globe	N. P. Peterson (964–W)	P.O. Box 1211.
California, Los Angeles	John T. McGill (Granite 3–0971, ext. 9881)	Geology Building, University of California.
Hawaii, Hawaii National Park	J. P. Eaton	Hawaiian Volcano Observatory.
Hawaii, Honolulu	Charles G. Johnson	District Bldg. 96, Fort Armstrong.
Kansas, Lawrence	Wm. D. Johnson, Jr. (Viking 3–2700)	c/o State Geological Survey, Lindley Hall, University of Kansas.
Kentucky, Lexington	P. W. Richards (4–2473)	915 S. Limestone Street.
Maryland, Beltsville	Allen V. Heyl (Tower 9–6430, ext. 468)	U.S. Geological Survey Building, Department of Agriculture Research Center.
Massachusetts, Boston	Lincoln R. Page (Kenmore 6–1444)	270 Dartmouth Street, Room 1.
Michigan, Iron Mountain	K. L. Wier (1736)	P.O. Box 45.
Mississippi, Jackson	Paul L. Applin (Fleetwood 5–3223)	1202½ North State Street.
New Mexico, Albuquerque	Charles B. Read (Chapel 7–0311, ext. 483).	P.O. Box 4083, Station A, Geology Building, University of New Mexico.
Ohio, Columbus	J. M. Schopf (Axminster 4–1810)	Orton Hall, Ohio State University, 155 South Oval Drive.
Ohio, New Philadelphia	James F. Pepper (4–2353)	P.O. Box 272; Muskingum Watershed Conservancy Building, 1319 Third Street, NW.
Pennsylvania, Mt. Carmel	Thomas M. Kehn (339–4390)	P.O. Box 366; 56 West 2d Street.
Puerto Rico, Roosevelt	Watson H. Monroe (San Juan 6–5340)	P.O. Box 803.
Tennessee, Knoxville	R. A. Laurence (2–7787)	11 Post Office Building.
Utah, Salt Lake City	Lowell S. Hilpert (Empire 4–2552)	506 Federal Building.
Vermont, Montpelier	W. M. Cady (Capitol 3–5311)	7 Langdon Street.
Washington, Spokane	A. E. Weissenborn (Temple 8–2084)	South 157 Howard Street.
Wisconsin, Madison	C. E. Dutton (Alpine 5–3311, ext. 2128)	213 Science Hall, University of Wisconsin.
Wyoming, Laramie	W. R. Keefer (Franklin 5–4495)	Geology Hall, University of Wyoming.

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[Temporary offices not included; list current as of March 15, 1961]

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Alabama, Montgomery	Lamar E. Carroon (s), (263–7521, ext. 396 and 397)	P.O. Box 56; 507 New Post Office Building.
Alabama, University	William J. Powell (g), (Plaza 2–8104)	P.O. Box V; Building 6, University of Alabama, Smith Woods.
Alaska, Anchorage	Roger M. Waller (g), (Broadway 2–8333)	P.O. Box 259; 501 Cordova Building, 555 Cordova Street.
Alaska, Juneau	Ralph E. Marsh (s), (6–2815)	P.O. Box 2659; Room 111, Federal Building.
Alaska, Palmer	Faulkner B. Walling (q), (Pioneer 5–3450)	P.O. Box 36; Wright Building.
Arizona, Phoenix	Herbert E. Skibitzke (g), (Alpine 8–5851, ext. 225)	Room 211, Ellis Building, 137 North 2d Avenue.
Arizona, Tucson	P. Eldon Dennis (g), and Douglas D. Lewis (s), (Main 3–7731, ext. 291 and 294)	P.O. Box 4126; Geology Building, University of Arizona.
Arizona, Yuma	Charles C. McDonald (g), (Sunset 3–7841)	P.O. Box 1488; 16 West 2d Street.
Arkansas, Fort Smith	John L. Saunders (s), (Sunset 3–6490)	P.O. Box 149; Room 6, Post Office Building.
Arkansas, Little Rock	Richard T. Sniegocki (g), (Franklin 2–4361, ext. 270)	217 Main Street.
California, Sacramento	Harry D. Wilson, Jr., (g), and Eugene Brown (q), (Ivanhoe 9–3661, ext. 322 and 381)	2929 Fulton Avenue.
Connecticut, Hartford	John Horton (s), (Jackson 7–3281, ext 257)	P.O. Box 715; 203 Federal Building.
Connecticut, Middletown	Robert V. Cushman (g), (Diamond 6–6986)	Post Office Building, Room 204.

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[Temporary offices not included; list current as of March 15, 1961]

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Delaware, Newark	Donald R. Rima (g), (Endicott 8–1197)	P.O. Box 24; 92 East Main Street.
Florida, Ocala	K. A. MacKichan (q), and Archibald O. Patterson (s), (Marion 2–6513).	P.O. Box 607; Building 211, Roosevelt Village.
Florida, Tallahassee	Matthew I. Rorabaugh (g), (223–2636)	Post Office Drawer 110, Gunter Building.
Georgia, Atlanta	Joseph T. Callahan (g), (Murray 8–5996)	19 Hunter Street, S.W., Room 416.
	Albert N. Cameron (s), (Trinity 6–3311, ext. 5218)	805 Peachtree Street, Room 609.
Hawaii, Honolulu	Dan A. Davis (g), (58–831, ext. 260 and 261)	Room 332, Home Insurance Building, 1100 Ward Avenue.
	Howard S. Leak (s), (58–831, ext. 251)	Room 330, Home Insurance Building, 1100 Ward Avenue.
Idaho, Boise	Wayne I. Travis (s), (4–4031), and Maurice J. Mundorff (g), (2–5441)	914 Jefferson Street, Room 215.
Illinois, Champaign	William D. Mitchell (g), (Fleetwood 6–5221)	605 South Neil Street.
Indiana, Indianapolis	Malcolm D. Hale (s), (Melrose 8–5541)	611 North Park Avenue, Room 407.
	Claude M. Roberts (g), (Melrose 2–1457)	611 North Park Avenue, Room 403.
Iowa, Iowa City	Vernal R. Bennion (s), (9345)	508 Hydraulic Laboratory.
	Walter L. Steinhilber (g), (8–1173)	Geology Annex- State University of Iowa.
Kansas, Lawrence	Vinton C. Fishel (g), (2700, ext. 559)	c/o University of Kansas.
Kansas, Topeka	Elwood R. Leeson (s), (Central 3–0521)	P.O. Box 856; 403 Federal Building.
Kentucky, Louisville	Gerth E. Hendrickson (g), and Floyd F. Schrader (s), (Juniper 4–1361, ext. 8235 and 8236)	522 West Jefferson Street, Room 310.
Louisiana, Baton Rouge	Fay N. Hanson (s), and Stanley F. Kapustka (q), (Dickens 3–6644)	Room 300, Leach Building, 315 Main Street.
	Rex R. Meyer (g), (Dickens 3–2873)	P.O. Box 8516, University Station; Room 43, Atkinson Hall, Louisiana State University.
Maine, Augusta	Gordon S. Hayes (s), and Glenn C. Prescott (g), (Mayfair 3–4511, ext. 250)	422 State House.
Maryland, Baltimore	Edmond G. Otton (g), (Belmont 5–0771)	103 Latrobe Hall, The Johns Hopkins University.
Maryland, College Park	John W. Odell (s), (Warfield 7–6348)	P.O. Box 37; 106 Engineering Classroom Building, University of Maryland.
Massachusetts, Boston	O. Milton Hackett (g), (Capitol 3–2725)	Room 847, Oliver Building, 141 Milk St.
	Charles E. Knox (s), (Capitol 3–2726)	Room 845, Oliver Building, 141 Milk St.
Michigan, Lansing	Arlington D. Ash (s), (Ivanhoe 9–2431), and Morris Deutsch (g), (Ivanhoe 9–7913)	407 Capitol Savings and Loan Building.
Minnesota, St. Paul	Leon R. Sawyer (s), (Capitol 2–8011, ext. 265)	1610 Post Office Building.
	Richmond F. Brown (g), (Capitol 2–8011, ext. 260)	1002 Post Office Building.
Mississippi, Jackson	Joe W. Lang (g), (Fleetwood 5–2724), and William H. Robinson (s), (Fleetwood 2–2718)	P.O. Box 2052; 402 High Street.
Missouri, Rolla	Harry C. Bolon (s), (Emerson 4–1599)	P.O. Box 138; 900 Pine Street.
Missouri, St. Louis	James W. Geurin (q), (Main 1–8100, ext. 2161)	Room 728, U.S. Court House and Customs House, 1114 Market Street.
Montana, Billings	Frank A. Swenson (g), (Alpine 9–2412)	P.O. Box 1818; Room 201, 202, 212; North 7th Street West.
Montana, Helena	Frank Stermitz (s), (442–4890)	P.O. Box 1696; 409 Federal Building.
Nebraska, Lincoln	Don M. Culbertson (q), (Hemlock 5–3273, ext. 346), Charles F. Keech (g), (Hemlock 5–3273, ext. 323), and Floyd F. Lefever (s), (Hemlock 5–3273, ext. 328)	Room 132, Nebraska Hall, 901 North 17th Street.
Nevada, Carson City	Leonard J. Snell (s), and Omar J. Loeltz (g), (Granite 2–1583)	P.O. Box B; 809 North Plaza Street.
New Mexico, Albuquerque	William E. Hale (g), (Chapel 7–0311, ext. 2248), and Jay M. Stow (q), (Chapel 7–0311, ext. 2249)	Box 4217, Geology Building, University of New Mexico.

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[Temporary offices not included; list current as of March 15, 1961]

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New Mexico, Sante Fe	Wilbur L. Heckler (s), (Yucca 2–1921)	P.O. Box 277; Room 224, Federal Courthouse.
New York, Albany	Ralph C. Heath (g), (Hobart 3–5581)	P.O. Box 229; 342 Federal Building.
	Donald F. Dougherty (s), (Hobart 3–5581)	P.O. Box 948; 343 Federal Building.
	Felix H. Pauszek (q), (Hobart 3–5581)	P.O. Box 68; 348 Federal Building.
North Carolina, Raleigh	Granville A. Billingsley (q); Philip M. Brown (g); and Edward B. Rice (s), (Temple 4–6427)	P.O. Box 2857; 4th Floor, Federal Building.
North Dakota, Bismarck	Harlan M. Erskine (s), (Capitol 3–3525)	P.O. Box 750; Room 7, 202½ 3d Street.
North Dakota, Grand Forks	Edward Bradley (g), (4–7221)	Box LL, University Station.
Ohio, Columbus	Lawrence C. Crawford (s), (Axminster 1–1602)	1509 Hess Street.
	George W. Whetstone (q), (Belmont 1–7553)	2822 East Main Street.
	Stanley E. Norris (g), (Capitol 1–6411, ext. 281)	Room 554, U.S. Post Office Building, 85 Marconi Boulevard.
Oklahoma, Norman	Alvin R. Leonard (g), (Jefferson 6–1818)	P.O. Box 780; Building 901, University of Oklahoma North Campus.
Oklahoma, Oklahoma City	Richard P. Orth (q), (Orange 7–5022)	P.O. Box 4355; 2800 South Eastern.
	Alexander A. Fishback, Jr. (s), (Central 6–5601, ext. 377 and 277)	Room 402, 1101 North Broadway.
Oregon, Portland	Kenneth N. Phillips (s), (Belmont 4–3361, ext. 239), Bruce L. Foxworthy (g), (Belmont 4–3361, ext. 236), and Leslie B. Laird (q), (Belmont 4–3361, ext. 241)	P.O. Box 3418; Interior Building, 1001 Northeast Lloyd Boulevard.
Pennsylvania, Harrisburg	Joseph E. Barclay (g), (Cedar 8–4925)	100 North Cameron Street.
	John J. Molloy (s), (Cedar 8–5151, ext. 2724)	P.O. Box 421; 490 Educational Building.
Pennsylvania, Philadelphia	Norman H. Beamer (q), (Market 7–6000, ext. 274 and 275)	2d and Chestnut Streets, Room 1302, U.S. Custom House.
Puerto Rico, San Juan	Dean B. Bogart (s), (3–3989)	1209 Avenida Fernandez, Juncos Santurce.
Rhode Island, Providence	William B. Allen (g), (Dexter 1–9312)	Room 401, Post Office Annex.
South Carolina, Columbia	Albert E. Johnson (s), (Alpine 2–2449)	1247 Sumter Street, 210 Creason Building.
	George E. Siple (g), (Alpine 3–7478)	Box 5314; 2215 Devine Street.
South Dakota, Huron	John E. Powell (g), (Elgyn 2–3756)	P.O. Box 1412; 231 Federal Building.
South Dakota, Pierre	John E. Wagar (s), (Capital 4–7856)	P.O. Box 216; 207 Federal Building.
Tennessee, Chattanooga	Joseph S. Cragwall, Jr. (s), (Amherst 6–2725)	823 Edney Building.
Tennessee, Memphis	Elliot M. Cushing (g), (Fairfax 3–4841)	Memphis General Depot, U.S. Army.
Tennessee, Nashville	Joe L. Poole (g), (Cypress 8–2849)	90 White Bridge Road.
Texas, Austin	Leon S. Hughes (q), Allen G. Winslow (g), and Trigg Twichell (s), (Greenwood 6–6981)	Vaughn Building, 807 Brazos Street.
Utah, Salt Lake City	John G. Connor (q), (Davis 2–3711)	P.O. Box 2657; Building 504, Fort Douglas.
	Harry D. Goode (g), (Empire 4–2552, ext. 434)	503–A Federal Building.
	Milton T. Wilson (s), (Empire 4–2552, ext. 436)	463 Federal Building
Virginia, Charlottesville	James W. Gambrell (s), (3–2127)	P.O. Box 3327, University Station; Natural Resources Building, McCormick Road.
Washington, Tacoma	Wilbur D. Simons (h), (Market 7–2678)	529 Perkins Building.
	Arthur A. Garrett (g), (Greenfield 4–4261)	3020 South 38th Street.
	Fred M. Veatch (s), (Fulton 3–1491)	207 Federal Building.
West Virginia, Charleston	Warwick L. Doll (s), (Dickens 4–1631, ext. 37)	Room 111, U.S. Courthouse.
West Virginia, Morgantown	Gerald Meyer (g), (Linden 2–8103)	405 Mineral Industries Building, West Virginia University.
Wisconsin, Madison	Charles R. Holt, Jr. (g), (Alpine 5–3311, ext. 2329).	175 Science Hall, University of Wisconsin.
	Kenneth B. Young (s), (Alpine 6–4411, ext. 494).	699 State Office Building.
Wyoming, Casper	George L. Haynes, Jr. (s), (2–6339)	P.O. Box 442; 150 South Jackson.
Wyoming, Cheyenne	Ellis D. Gordon (g), (634–2731, ext. 37)	Room 03–B, 2002 Capitol Avenue.
Wyoming, Worland	Thomas F. Hanley (q), (Fireside 7–2181)	1214 Big Horn Avenue.

*The small letter in parentheses following each official's name signifies his branch affiliation in Water Resources Division as follows: g—Ground Water Branch; q—Quality of Water Branch; s—Surface Water Branch; h—General Hydrology Branch.

GEOLOGICAL SURVEY OFFICES IN OTHER COUNTRIES

GEOLOGIC DIVISION

Location	*Geologist in charge*	*Mailing Address*
Bolivia, La Paz	Charles M. Tschanz	U.S. Geological Survey, USOM/LaPaz, c/o American Embassy, La Paz, Bolivia.
Brazil, Belo Horizonte	J. V. N. Dorr, II	U.S. Geological Survey, Caixa Postal 107, Belo Horizonte, Minas Gerais, Brazil.
Brazil, Porto Alegre	A. J. Bodenlos	U.S. Geological Survey, c/o American Consulate General–P.A., APO 676, New York, New York.
Brazil, Rio de Janeiro	A. J. Bodenlos	U.S. Geological Survey, USOM, American Embassy, APO 676, New York, New York
Brazil, Sao Paulo	A. J. Bodenlos	U.S. Geological Survey, c/o American Consulate General–S.P., APO 676, New York, New York.
Chile, Santiago	W. D. Carter	U.S. Geological Survey, c/o American Embassy, Santiago, Chile.
Germany, Heidelburg	R. H. Bernard	U.S. Geological Survey Team (Europe), 139 Engineer Detachment (Terrain), APO 403, New York, New York.
Indonesia, Bandung	Robert Johnson	U.S. Geological Survey, USOM to Indonesia, c/o American Embassy, Djakarta, Indonesia.
Libya, Tripoli	Gus Goudarzi	U.S. Geological Survey, USOM, APO 231, c/o Postmaster, New York, New York.
Mexico, México, D.F.	Ralph Miller	U.S. Geological Survey, USOM, American Embassy, México, D.F., Mexico.
Pakistan, Quetta	John A. Reinemund	U.S. Geological Survey, USOM, American Embassy, APO 271, New York, New York.
Philippines, Manila	Joseph F. Harrington	U.S. Geological Survey, c/o American Embassy, APO 928, San Francisco, California.
Taiwan, Taipei (Formosa)	Samuel Rosenblum	U.S. Geological Survey, ICA/MSM/China, APO 63, San Francisco, California.
Thailand, Bangkok	Louis S. Gardner	U.S. Geological Survey, c/o American Embassy, APO 146, Box B, San Francisco, California.
Turkey, Istanbul	Quentin D. Singewald	U.S. Geological Survey/ICA, c/o American Embassy, APO 380, New York, New York.

WATER RESOURCES DIVISION

[List current as of March 15, 1961]

Location	*Official in charge*	*Mailing Address*
Afghanistan, Lashkar Gah	R. H. Brigham	U.S. Geological Survey, USOM-Kabul/Lashkar Gah, Department of State Mail Room, Washington 25, D.C.
Chile, Santiago	R. J. Dingman	U.S. Geological Survey, c/o American Embassy, Santiago, Chile.
Iran, Teheran	A. F. Pendleton	U.S. Geological Survey, USOM-Agriculture Division, APO 205, New York, New York.
Libya, Benghazi	J. R. Jones	U.S. Geological Survey, USOM, APO 231 (Box B), c/o Postmaster, New York, New York.
Pakistan, Lahore	D. W. Greenman	U.S. Geological Survey, USOM, American Embassy, APO 271, New York, New York.
Philippines, Manila	C. R. Murray	U.S. Geological Survey, USOM/ICA (Manila, P.I.), APO 928, San Francisco, California.
Tunisia, Tunis	H. E. Thomas	U.S. Geological Survey, USOM to Tunisia, c/o American Embassy, Department of State Mail Room, Washington 25, D.C.
Turkey, Ankara	C. C. Yonker	U.S. Geological Survey, c/o ICA, APO 254, New York, New York.
United Arab Republic (Egypt), Cairo	H. A. Waite	U.S. Geological Survey, USOM/Cairo, Department of State Mail Room, Washington 25, D.C.

COOPERATING AGENCIES

FEDERAL AGENCIES

Agricultural Research Service
Air Force
- Cambridge Research Center
- Technical Application Center

Army
- Corps of Engineers

Atomic Energy Commission
- Division of Biology and Medicine
- Division of Reactor Development
- Military Application Division
- Office of Isotope Development
- Raw Materials Division
- Research Division
- Special Projects Division

Bonneville Power Administration
Bureau of Indian Affairs
Bureau of Land Management
Bureau of Mines
Bureau of Public Roads
Bureau of Reclamation
Bureau of Sport Fisheries and Wildlife
Coast Guard
Department of Defense
- Advanced Research Projects Agency

Department of Justice
Department of State
Federal Housing Administration
Federal Power Commission
Forest Service
International Cooperation Administration
Maritime Administration
National Park Service
Navy
- Bureau of Yards and Docks
- Office of Naval Research

National Aeronautical and Space Administration
National Science Foundation
Office of Minerals Exploration
Public Health Service
Soil Conservation Service
Tennessee Valley Authority
U.S. Study Commission—Southeast River Basins
U.S. Study Commission—Texas
Veterans Administration
Weather Bureau

STATE, COUNTY, AND MUNICIPAL AGENCIES

Alabama:
- Geological Survey of Alabama
- Alabama Highway Department
- Department of Conservation
- Water Improvement Commission
- Calhoun County Board of Revenue
- Morgan County Board of Revenue and Control
- Tuscaloosa County Board of Revenue
- City of Athens
- City of Huntsville
- City of Russellville Water Board

Alaska:
- Alaska Department of Natural Resources
- Alaska Department of Health

Arizona:
- 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
- Navajo Tribal Council
- Buckeye Irrigation Company
- Gila Valley Irrigation District
- Salt River Valley Water Users Association
- San Carlos Irrigation and Drainage District

Arkansas:
- Arkansas Geological and Conservation Commission
- Arkansas State Highway Commission
- University of Arkansas—Agricultural Experiment Station
- University of Arkansas—Engineering Experiment Station

California:
- California Department of Natural Resources, Division of Mines
- State Department of Water Resources
- Alameda County Water District
- Calaveras County Water District
- Contra Costa County Flood Control and Water Conservation District
- County of Los Angeles, Department of County Engineers
- Montecito County Water District
- Monterey County Flood Control and Water Conservation District
- North Marin County Water District
- Orange County Flood Control District
- Santa 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
- 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
- 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

STATE, COUNTY, AND MUNICIPAL AGENCIES—Continued

Colorado:
- 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

Connecticut:
- Connecticut Geological and Natural History Survey
- 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
- Chester County Soil Conservation District
- City of Newark

District of Columbia:
- District of Columbia Department of Sanitary Engineering

Florida:
- Florida Geological Survey
- State Board of Parks and Historic Memorials
- State Road Department of Florida
- Collier County—Board of County Commissioners
- Dade County—Board of County Commissioners
- Hillsborough County—Board of County Commissioners
- 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 Miami—Department of Water and Sewerage
- City of Miami Beach
- City of Naples
- City of Pensacola
- 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:
- Commission of Public Lands, Hawaii
- State Department of Land and Natural Resources

Idaho:
- Idaho Department of Highways
- Idaho Department of Reclamation
- Idaho State Fish and Game Commission

Illinois:
- State Department of Public Works and Buildings—Division of Highways
- State Department of Public Works and Buildings—Division of Waterways
- State Department of Registration and Education
- Cook County Department of Highways
- Fountain Head Drainage District

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 College—Agricultural Experiment Station
- Board of Supervisors, Linn County
- City of Fort Dodge—Department of Utilities

Kansas:
- State Geological Survey of Kansas, University of Kansas
- State Board of Agriculture, Division of Water Resources
- State Highway Commission
- State Water Resources Board
- City of Wichita, Water Supply and Sewage Treatment Division

Kentucky:
- Kentucky Geological Survey, University of Kentucky

Louisiana:
- State Geological Survey
- State Department of Conservation
- State Department of Highways
- State Department of Public Works

Maine:
- Maine Public Utilities Commission

Maryland:
- State Department of Geology, Mines, and Water Resources
- Maryland National Capital Park and Planning Commission
- Anne Arundel County Planning Commission
- Commissioners of Charles County
- City of Baltimore

Massachusetts:
- State Department of Public Works
- Massachusetts Department of Public Health
- Massachusetts Water Resources Commission
- Boston Metropolitan District Commission

Michigan:
- Department of Conservation, Geological Survey Division
- 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

STATE, COUNTY, AND MUNICIPAL AGENCIES—Continued

Mississippi:
- Mississippi Board of Water Commissioners
- Mississippi State Highway Department
- Jackson County, Mississippi, Port Authority
- City of Jackson
- Mississippi Industrial and Technological Research Commission

Missouri:
- Division of Geological Survey and Water Resources
- Missouri State Highway Commission
- Curators of the University of Missouri

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, University of Nevada
- Department of Conservation and Natural Resources

New Hampshire:
- New Hampshire Water Resources Board

New Jersey:
- State Department of Conservation and Economic Development
- Rutgers University, the State University of New Jersey
- North Jersey District Water Supply Commission
- Passaic Valley Water Commission

New Mexico:
- State Bureau of Mines and Mineral Resources
- State Engineer
- State Highway Department
- New Mexico Institute of Mining and Technology
- Board of Hudson River-Black River Regulating District
- Interstate Stream Commission
- Pecos River Commission
- Rio Grande Compact Commission

New York:
- State Conservation Department
- State Department of Health
- State Department of Public Works
- 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—Continued
- New York City Department of Water Supply; Gas and Electricity
- Village of Nyack—Board of Water Commissioners
- Schenectady Water Department
- Brighton Sewer District #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 Greensboro
- City of Waynesville

North Dakota:
- North Dakota Geological Survey
- State Highway Department
- State Water Conservation Commission

Ohio:
- Ohio Department of Natural Resources—Division of Water
- Hamilton County, Board of County Commissioners
- City of Columbus—Department of Public Service
- Miami Conservancy District
- Ohio River Valley Water Sanitation Commission

Oklahoma:
- Oklahoma Geological Survey
- Oklahoma State Department of Health
- Oklahoma Water Resources Board
- Oklahoma City Water Department

Oregon:
- Oregon Agricultural Experiment Station
- State Highway Department
- Oregon Fish Commission
- Oregon State College—Department of Fish and Game Management
- Oregon State Sanitary Authority
- County Court of Douglas County
- County Court of Morrow 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
- City of Toledo
- Coos Bay North Bend Water Board

Pennsylvania:
- Bureau of Topographic and Geologic Survey, Department of Internal Affairs
- State Department of Agriculture
- State Department of Forests and Waters
- City of Bethlehem
- City of Harrisburg
- City of Philadelphia

Rhode Island:
- State of Rhode Island and Providence Plantations
- Rhode Island Water Resources Coordinating Board
- State Department of Public Works—Division of Harbors and Rivers

STATE, COUNTY, AND MUNICIPAL AGENCIES—Continued

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 Industrial Development Expansion Agency
- South Dakota Department of Highways
- South Dakota Water Resources Commission

Tennessee:
- Tennessee Department of Conservation and Commerce—Division of Geology
- Tennessee Department of Conservation and Commerce—Division of Water Resources
- Tennessee Game and Fish Commission
- Tennessee Department of Highways
- Tennessee Department of Public Health—Stream Pollution Control
- City of Chattanooga
- Memphis Board of Light, Gas, and Water Commissioners, Water Division

Texas:
- State Board of Water Engineers
- Texas Department of Agriculture
- Texas A & M Research Foundation
- Pecos River Commission
- Rio Grande Compact Commission
- Sabine River Compact Administration

Utah:
- Utah State Engineer
- Utah Water and Power Board
- State Road Commission of Utah
- University of Utah
- Salt Lake County
- Bear River Compact Commission

Vermont:
- State Water Conservation Board

Virginia:
- Department of Highways
- County of Chesterfield
- County of Fairfax
- City of Alexandria
- City of Charlottesville

Virginia—Continued
- 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
- State Department of Conservation, Division of Water Resources
- State Department of Fisheries
- State Department of Game
- State Department of Highways
- State Pollution Control Commission
- Municipality of Metropolitan Seattle
- Seattle Light Department
- Seattle Water Department
- City of Tacoma

West Virginia:
- State Geological and Economic Survey
- State Water Resources Commission
- Clarksburg Water Board
- Ohio River Valley Water Sanitation Commission

Wisconsin:
- Wisconsin Geological and Natural History Survey, University of Wisconsin
- 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 Natural Resource Board
- City of Cheyenne—Board of Public Utilities

Commonwealth:
- Puerto Rico:
  - Puerto Rico Water Resources Authority

Unincorporated Territories:
- American Samoa:
  - Government of American Samoa
- Guam:
  - Government of Guam

INVESTIGATIONS IN PROGRESS IN THE GEOLOGIC AND WATER RESOURCES DIVISIONS DURING THE FISCAL YEAR 1961

Investigations in progress in the Geologic and Water Resources Divisions during the fiscal year 1961 are listed below, together with the names and headquarters of the individuals in charge of each. The list includes some projects that have been completed except for publication of final results, and a few that have been temporarily recessed. Headquarters for major offices are indicated by the initials (W) for Washington, D.C., (D) Denver, Colo., and (M) for Menlo Park, Calif. Headquarters in other cities are indicated by name; see list of offices on preceding pages for addresses. For projects in the Water Resources Division, a lower case letter before the city initial or name indicates the unit under which the project is administered, g, Branch of Ground Water; s, Branch of Surface Water; q, Branch of Quality of Water; h, Branch of General Hydrology; and w, Water Resources Division.

Projects that include a significant amount of geologic mapping are indicated by asterisks. One asterisk (*) indicates mapping at a scale of a mile to the inch or larger, and two asterisks (**) indicate mapping at a scale smaller than a mile to the inch.

The projects are classified by State or similar unit and are repeated as necessary to show work in more than one State. However, projects that deal with areas larger than 4 States are listed only under the heading, "Large Regions of the United States".

Topical investigations, such as commodity studies, studies of geologic and hydrologic processes and methods, are listed under the single most appropriate topical heading, even though the work may deal with more than one subject. Topical investigations that involve specific areas are also listed under regional headings.

REGIONAL INVESTIGATIONS

Large regions of the United States:

Geologic map of the United States
P. B. King (M)

Gravity map of the United States
H. R. Joesting (W)

Coal fields of the United States
J. Trumbull (W)

Paleotectonic maps of the late Paleozoic
E. D. McKee (D)

Synthesis of geologic data on Atlantic Coastal Plain and Continental Shelf
J. E. Johnston (W)

Aeromagnetic profiles over the Atlantic Continental Shelf and Slope
E. R. King (W)

Cross-country aeromagnetic profiles
E. R. King (W)

Aerial radiological monitoring surveys, Northeastern United States
P. Popenoe (W)

Geology of the Piedmont region of the Southeastern States (monazite)
W. C. Overstreet (W)

Igneous rocks of Southeastern United States
C. Milton (W)

Geophysical studies of Appalachian structure
E. R. King (W)

Geology of the Appalachian Basin with reference to disposal of high-level radioactive wastes
G. W. Colton (W)

Lower Paleozoic stratigraphic paleontology, Eastern United States
R. B. Neuman (W)

Ordovician stratigraphic paleontology of the Great Basin and Rocky Mountains
R. J. Ross, Jr. (D)

Large regions of the United States—Continued

Silurian and Devonian stratigraphic paleontology of the Great Basin and Pacific Coast
C. W. Merriam (W)

Upper Paleozoic stratigraphic paleontology, Western United States
J. T. Dutro, Jr. (W)

Mesozoic stratigraphic paleontology, Atlantic and Gulf coasts
N. F. Sohl (W)

Mesozoic stratigraphic paleontology, Pacific coast
D. L. Jones (M)

Cordilleran Triassic faunas and stratigraphy
N. J. Silberling (M)

Jurassic stratigraphic palenontology of North America
R. W. Imlay (W)

Cretaceous stratigraphy and paleontology, western interior United States
W. A. Cobban (D)

Cenozoic mollusks, Atlantic and Gulf Coastal plains
D. Wilson (W)

Middle and Late Tertiary history of parts of the Northern Rocky Mountains and Great Plains
N. M. Denson (D)

Summary of the ground-water situation in the United States
C. L. McGuinness (g, W)

Water use in the United States, 1960
K. A. MacKichan (h, W)

Long term Nation wide chronologies of hydrologic events
W. D. Simons (h, Tacoma, Wash.)

Collection of basic records on chemical quality and sediment of surface waters of the United States
S. K. Love (q, W)

Fluvial denudation in the United Sates. Phase 2.—Variance in water quality and environment
F. H. Rainwater (q, W)

Large regions of the United States—Continued
- Chemical characteristics of larger public water supplies in the United States
  - C. N. Durfor (q, W)
- Spatial distribution of chemical constituents in ground water, Eastern United States
  - W. Back (g,W)
- Geology and ground-water hydrology of the Atlantic and Gulf Coastal Plains as related to disposal of radioactive wastes
  - H. E. LeGrand (w, W)
- Fluvial sediments and solutes in the Potomac River basin
  - J. W. Wark (q, Rockville, Md.)
- Geology and hydrology of the Central and Northeastern States as related to the management of radioactive materials
  - W. C. Rasmussen (g, Newark, Del.)
- Some discharge relationships of the Red River of the South
  - G. H. Dury (w, W)
- Mississippi Embayment hydrology
  - E. M. Cushing (g, Memphis, Tenn.)
- Problems of contrasting ground water media in consolidated rocks in humid areas, Southeastern United States
  - H. E. LeGrand (w, W)
- Geology and hydrology of Great Plains States as related to the management of radioactive materials
  - W. C. Rasmussen (g, Newark, Del.)
- Geology and hydrology of the western states as related to the management of radioactive materials
  - R. W. Maclay (g, St. Paul, Minn.)
- Appraisal of water resources of Upper Colorado River basin, Colorado, Wyoming, Utah, New Mexico, and Arizona
  - W. V. Iorns (q, Salt Lake City, Utah)
- Snake River Basin—quality of surface waters
  - L. B. Laird (q, Portland, Oreg.)
- Effect of mechanical treatment on arid land in the Western United States
  - F. A. Branson, (h, D)
- Hydrology of the public domain
  - H. V. Peterson (h, M)
- Water-supply exploration on the public domain (Western States)
  - G. G. Parker (h, D)
- Hydrologic atlas of Pacific Northwest
  - W. D. Simons (h, Tacoma, Wash.)
- Water resources of entire states
  - K. A. MacKichan (h, W)

Alabama:
- Coal resources
  - W. C. Culbertson (D)
- Clinton iron ores of the southern Appalachians
  - R. P. Sheldon (D)
- *Warrior quadrangle (coal)
  - W. C. Culbertson (D)
- Pre-Selma Cretaceous rocks of Alabama and adjacent States
  - L. C. Conant (Tripoli, Libya)
- Mesozoic rocks of Florida and eastern Gulf coast
  - P. L. Applin (Jackson, Miss.)
- Limestone terrane hydrology
  - W. J. Powell (g, Tuscaloosa, Ala.)

Alabama—Continued
- Artesian water in Tertiary limestones in Florida, southern Georgia and adjacent parts of Alabama and South Carolina
  - V. T. Stringfield (w, W)
- Unit graphs and infiltration rates, Alabama (surface water)
  - L. B. Peirce (s, Montgomery, Ala.)
- Stream profiles, Alabama (surface water)
  - L. B. Peirce (s, Montgomery, Ala.)
- Bridge-site studies, Alabama
  - L. B. Peirce (s, Montgomery, Ala.)
- Local floods, Alabama
  - L. B. Peirce (s, Montgomery, Ala.)
- Extending small-area flood records, Alabama
  - L. B. Peirce (s, Montgomery, Ala.)
- Autauga County (ground water)
  - J. C. Scott (g, Tuscaloosa, Ala.)
- Bullock County (ground water)
  - J. C. Scott (g, Tuscaloosa, Ala.)
- Calhoun County (ground water)
  - J. C. Warman (g, Tuscaloosa, Ala.)
- Geologic and hydrologic profiles in Clarke County
  - L. D. Toulmin (g, Tuscaloosa, Ala.)
- Colbert County (ground water)
  - H. B. Harris (g, Tuscaloosa, Ala.)
- Escambia County (ground water)
  - J. W. Cagle (g, Tuscaloosa, Ala.)
- Etowah County (ground water)
  - L. V. Causey (g, Tuscaloosa, Ala.)
- Franklin County (ground water)
  - R. R. Peace (g, Tuscaloosa, Ala.)
- Hale County (ground water)
  - Q. F. Paulson (g, Tuscaloosa, Ala.)
- Lauderdale County (ground water)
  - H. B. Harris (g, Tuscaloosa, Ala.)
- Limestone County (ground water)
  - W. M. McMaster (g, Tuscaloosa, Ala.)
- Morgan County (ground water)
  - C. L. Dodson (g, Tuscaloosa, Ala.)
- Pickens County (ground water)
  - J. G. Newton (g, Tuscaloosa, Ala.)
- St. Clair County (ground water)
  - L. V. Causey (g, Tuscaloosa, Ala.)
- Tuscaloosa County (ground water)
  - Q. F. Paulson (g, Tuscaloosa, Ala.)
- Athens and vicinity (ground water)
  - W. M. McMaster (g, Tuscaloosa, Ala.)
- Geologic and hydrologic profile along the Chattahoochee River
  - L. D. Toulmin (g, Tuscaloosa, Ala.)
- Huntsville and Madison County (ground water)
  - T. H. Sanford (g, Tuscaloosa, Ala.)
- Russellville and vicinity (ground water)
  - R. R. Peace (g, Tuscaloosa, Ala.)
- Sylacauga Area (ground water)
  - G. W. Swindel (g, Tuscaloosa, Ala.)
- Sylacauga area (petrography)
  - C. E. Shaw (g, Tuscaloosa, Ala.)

Alaska:
- General geology:
  - Index of literature on Alaskan geology
    - E. H. Cobb (M)

Alaska—Continued
General geology—Continued
Tectonic map
G. Gryc (W)
Glacial map
D. M. Hopkins (M)
Physiographic divisions
C. Wahrhaftig (M)
Rock types map of Alaska
L. A. Yehle (W)
Landform map of Alaska
H. W. Coulter (W)
Vegetation map of Alaska
L. A. Spetzman (W)
Climatic map of Alaska
A. T. Fernald (W)
Compilation of geologic maps, 1:250,000 quadrangles
W. H. Condon (M)
**Regional geology and mineral resources, southeastern Alaska
R. A. Loney (M)
*Eastern Aleutian Islands
R. E. Wilcox (D)
*Western Aleutian Islands
R. E. Wilcox (D)
*Surficial geology of the Barter Island-Mt. Chamberlin area
C. R. Lewis (W)
**Buckland and Huslia Rivers area, west-central Alaska
W. W. Patton, Jr. (M)
**Eastern Chugach Mountains traverse
D. J. Miller (M)
**Fairbanks quadrangle
F. R. Weber (College, Alaska)
*Petrology and volcanism, Katmai National Monument
G. H. Curtis (M)
**Livengood quadrangle
B. Taber (M)
*Mount Michelson area
E. G. Sable (Ann Arbor, Mich.)
*Windy-Curry area
R. Kachadoorian (M)
*Southern Wrangell Mountains
E. M. MacKevett, Jr. (M)
**Lower Yukon-Norton Sound region
J.M. Hoare (M)
**Upper Yukon River traverse
E. E. Brabb (M)
Mineral resources:
Metallogenic provinces
C. L. Sainsbury (M)
Geochemical prospecting techniques
R. M. Chapman (D)
Miscellaneous mineral resource investigations
E. M. MacKevett, Jr. (M)
**Klukwan iron district
E. C. Robertson (W)
Quicksilver deposits, southwestern Alaska
E. M. MacKevett, Jr. (M)
**Lower Kuskokwim-Bristol Bay region (mercury-antimony-zinc)
J. M. Hoare (M)
**Southern Brooks Range (copper, precious metals)
W. P. Brosgé (M)

Alaska—Continued
Mineral resources—Continued
*Nome C-1 and D-1 quadrangles (gold)
C. L. Hummel (M)
*Tofty placer district (gold, tin)
D. M. Hopkins (M)
Seward Peninsula tin investigations
P. L. Killeen (W)
Uranium-thorium reconnaissance
E. M. MacKevett, Jr. (M)
*Beluga-Yentna area (coal)
F. F. Barnes (M)
*Matanuska coal field
F. F. Barnes (M)
Matanuska stratigraphic studies (coal)
A. Grantz (M)
*Nenana coal investigations
C. Wahrhaftig (M)
**Gulf of Alaska province (petroleum)
D. J. Miller (M)
**Northern Alaska petroleum investigations
G. Gryc (W)
*Iniskin-Tuxedni region (petroleum)
R. L. Detterman (M)
**Nelchina area (petroleum)
A. Grantz (M)
**Lower Yukon-Koyukuk area (petroleum)
W. W. Patton, Jr. (M)
*Heceta-Tuxekan area (high-calcium limestone)
G. D. Eberlein (M)
Engineering geology and permafrost:
Engineering soils map of Alaska
T. N. V. Karlstrom (W)
*Surficial and engineering geology studies and construction materials sources
T. L. Péwé (College, Alaska)
Arctic ice and permafrost studies
A. H. Lachenbruch (M)
Origin and stratigraphy of ground ice in central Alaska
T. L. Péwé (College, Alaska)
*Surficial geology of the Anchorage-Matanuska Glacier area (construction-site planning)
T. N. V. Karlstrom (W)
*Surficial geology of the Big Delta Army Test Area (construction-site planning)
G. W. Holmes (W)
*Surficial geology of the Big Delta-Fairbanks area (construction-site planning)
H. L. Foster (W)
*Nuclear test-site evaluation, Chariot
G. D. Eberlein (M)
*Surficial geology of the lower Chitina Valley (construction-site planning)
L. A. Yehle (W)
*Surficial geology of the northeastern Copper River (construction-site planning)
O. J. Ferrians, Jr. (Glennallen, Alaska)
*Surficial geology of the southeastern Copper River (construction-site planning)
D. R. Nichols (W)
*Surficial geology of the southwestern Copper River basin (construction-site planning)
J. R. Williams (W)

Alaska—Continued
Engineering geology and permafrost—Continued
*Surficial geology of the eastern Denali Highway (construction-site planning)
D. R. Nichols (W)
*Surficial geology of the Johnson River district (construction-site planning)
H. L. Foster (W)
**Surficial geology of the Kenai lowland (construction-site planning)
T. N. V. Karlstrom (W)
**Surficial geology of the Kobuk River valley (construction-site planning)
A. T. Fernald (W)
*Mt. Hayes D-3 and D-4 quadrangles (construction-site planing)
T. L. Péwé (College, Alaska)
*Surficial geology of the Seward-Portage Railroad (construction-site planning)
T. N. V. Karlstrom (W)
*Surficial geology of the Slana-Tok area (construction-site planning)
H. R. Schmoll (W)
*Surficial geology of the Susitna-Maclaren River area (construction-site planning)
D. R. Nichols (W)
**Engineering geology of Talkeetna-McGrath highway
Florence Weber (College, Alaska)
*Surficial geology of the Upper Tanana River (construction-site planning)
A. T. Fernald (W)
*Surficial geology of the Valdez-Tiekel belt (construction-site planning)
H. W. Coulter (W)
**Engineering geology of Yukon-Koyukuk lowland
F. R. Weber (College, Alaska)
Paleontology:
Central Alaska Cenozoic
D. M. Hopkins (M)
Cenozoic mollusks
F. S. MacNeil (M)
Cretaceous Foraminifera of the Nelchina area
H. R. Bergquist (W)
Geophysical studies:
Aeromagnetic surveys
G. E. Andreasen (W)
Regional gravity surveys
D. F. Barnes (M)
Aerial radiological monitoring surveys, Chariot site
R. G. Bates (W)
Water resources:
General inventory of ground water
R. M. Waller (g, Anchorage, Alaska)
Relationship of permafrost to ground water
J. R. Williams (g, Anchorage, Alaska)
Water-supply investigations for U.S. Air Force
A. J. Feulner (g, Anchorage, Alaska)
Anchorage area (ground water)
D. J. Cederstrom (g, W)
Water utilization at Anchorage
R. M. Waller (g, Anchorage, Alaska)
Chugiak area (ground water)
R. M. Waller (g, Anchorage, Alaska)
Fairbanks area (ground water)
D. J. Cederstrom (g, W)

Alaska—Continued
Water resources—Continued
Fort Greely (ground water)
R. M. Waller (g, Anchorage, Alaska)
Homer area (ground water)
R. M. Waller (g, Anchorage, Alaska)
Project Chariot (ground water)
R. M. Waller (g, Anchorage, Alaska)
Arizona:
General geology:
Arizona state geologic map
J. R. Cooper (D)
Devonian rocks and paleogeography of central Arizona
C. Teichert (D)
Devonian rocks of northwestern Arizona
C. Teichert (D)
Stratigraphy of the Redwall limestone
E. D. McKee (D)
History of Supai-Hermit formations
E. D. McKee (D)
*Geology of southern Cochise County
P. T. Hayes (D)
*Elgin quadrangle
R. B. Raup (M)
*Upper Gila River basin, Arizona-New Mexico
R. B. Morrison (D)
*Holy Joe Peak quadrangle
M. H. Krieger (M)
Lochiel and Nogales quadrangles
F. S. Simons (D)
Meteor Crater
E. M. Shoemaker (M)
Diatremes, Navajo and Hopi Indian Reservations
E. M. Shoemaker (M)
*Eastern Mogollon Rim area
E. J. McKay (D)
Mineral resources:
Geochemical halos of mineral deposits, California and Arizona
L. C. Huff (D)
Studies of uranium deposits
H. C. Granger (D)
**Compilation of Colorado Plateau geologic maps (uranium, vanadium)
D. G. Wyant (D)
Relative concentrations of chemical elements in rocks and ore deposits of the Colorado Plateau (uranium, vanadium, copper)
A. T. Miesch (D)
Uranium-vanadium deposits in sandstone, with emphasis on the Colorado Plateau
R. P. Fischer (D)
Colorado Plateau botanical prospecting studies
F. J. Kleinhampl (M)
Clay studies, Colorado Plateau
L. G. Schultz (D)
Lithologic studies, Colorado Plateau
R. A. Cadigan (D)
Stratigraphic studies, Colorado Plateau (uranium, vanadium)
L. C. Craig (D)
Triassic stratigraphy and lithology of the Colorado Plateau (uranium, copper)
J. H. Stewart (D)

Arizona—Continued
Mineral resources—Continued
San Rafael group stratigraphy, Colorado Plateau (uranium)
J. C. Wright (D)
*Carrizo Mountains area, Arizona-New Mexico (uranium)
J. D. Strobell (D)
Uranium deposits of the Dripping Spring quartzite of southeastern Arizona
H. C. Granger (D)
East Vermillion Cliffs area (uranium, vanadium)
R. G. Peterson (Boston, Mass.)
*Bradshaw Mountains (copper)
C. A. Anderson (W)
*Christmas quadrangle (copper, iron)
C. R. Willden (M)
*Globe-Miami area (copper)
N. P. Peterson (Globe, Ariz.)
*Klondyke quadrangle (copper)
F. S. Simons (D)
*Contact-metamorphic deposits of the Little Dragoons area (copper)
J. R. Cooper (D)
*Mammoth and Benson quadrangles (copper)
S. C. Creasey (M)
*Prescott-Paulden area (copper)
M. H. Krieger (M)
*Twin Buttes area (copper)
J. R. Cooper (D)
*McFadden Peak and Blue House Mountain quadrangles (asbestos)
A. F. Shride (D)
*Fuels potential of the Navajo Reservation, Arizona and Utah
R. B. O'Sullivan (D)
Geophysical studies:
Great Basin geophysical studies
D. R. Mabey (M)
Colorado Plateau regional geophysical studies
H. R. Joesting (W)
Water resources:
The geohydrologic environment as related to water utilization in arid lands
E. S. Davidson (g, Tucson, Ariz.)
Evapotranspiration theory and measurement
O. E. Leppanen (h, Phoenix, Ariz.)
Hydrologic effect of vegetation modification
R. C. Culler (h, Tucson, Ariz.)
Use of water by saltcedar in evapotranspirometer compared with energy budget and mass transfer computation (Buckeye)
T. E. A. Van Hylckama (h, Phoenix, Ariz.)
Lower Colorado River Basin hydrology
C. C. McDonald (g, Yuma, Ariz.)
Central Apache County (ground water)
J. P. Akers (g, Tucson, Ariz.)
Northwestern Pinal County (ground water)
W. F. Hardt (g, Tucson, Ariz.)
Big Sandy valley (ground water)
W. Kam (g, Tucson, Ariz.)
Effect of removing riparian vegetation, Cottonwood Wash, Arizona (water)
J. E. Bowie (s, Tucson, Ariz.)

Arizona—Continued
Water resources—Continued
Flagstaff area (ground water)
J. P. Akers (g, Tucson, Ariz.)
Hydrologic regimen and volumetric analysis of Upper Gila River
Sumsion, C. T. (h, Tucson, Ariz.)
Fort Huachuca (ground water)
H. G. Page (g, Tucson, Ariz.)
Luke Air Force Base (ground water)
J. M. Cahill (g, Tucson, Ariz.)
Navajo Indian Reservation (ground water)
M. E. Cooley (g, Tucson, Ariz.)
Papago Indian Reservation (ground water)
L. A. Heindl (g, W)
Rainbow Valley-Waterman Wash (ground water)
F. R. Twenter (g, Tucson, Ariz.)
Rillito basin, Arizona (surface water)
J. J. Ligner (s, Tucson, Ariz.)
Deep aquifers in the Salt River valley
D. G. Metzger (g, Tucson, Ariz.)
San Simon basin (ground water)
N. D. White (g, Tucson, Ariz.)
Snowflake-Taylor area (ground water)
P. W. Johnson (g, Tucson, Ariz.)
Study of channel flood-plain aggradation Tusayan Washes
R. F. Hadley (h, D)
Verde Valley (ground water)
D. G. Metzger (g, Tucson, Ariz.)
Willcox basin (ground water)
S. G. Brown (g, Tucson, Ariz.)
Arkansas:
Barite deposits
D. A. Brobst (D)
*Arkansas Basin (coal)
B. R. Haley (D)
*Ft. Smith district, Arkansas and Oklahoma (coal and gas)
T. A. Hendricks (D)
Magnet Cove niobium investigations
L. V. Blade (Paducah, Ky.)
*Northern Arkansas oil and gas investigations
E. E. Glick (D)
Aeromagnetic studies in the Newport, Arkansas, and Ozark bauxite areas
A. Jaspersen (W)
Artificial recharge of aquifers
R. T. Sniegocki (g, Little Rock, Ark.)
Flood investigations
R. C. Christensen (s, Fort Smith, Ark.)
Low-flow gaging
J. D. Warren (s, Fort Smith, Ark.)
Bradley, Calhoun, and Ouachita Counties (ground water)
D. R. Albin (g, Little Rock, Ark.)
Crittenden County (ground water)
R. O. Plebuch (g, Little Rock, Ark.)
Ground water along U.S. Highway 70 from Pulaski County to Crittenden County
H. N. Halberg (g, Little Rock, Ark.)
Arkansas River Valley
M. S. Bedinger (g, Little Rock, Ark.)
Arkansas River Valley reconnaissance (ground water)
R. M. Cordova (g, Little Rock, Ark.)
Artificial recharge, Grand Prairie Region (ground water)
R. T. Sniegocki (g, Little Rock, Ark.)

Arkansas—Continued
Smackover Creek basin (chemical quality of surface waters)
H. G. Jeffery (q, Fayetteville, Ark.)
Surface-water resources of the White River basin, 1948–59
M. E. Schroeder (q, Fayetteville, Ark.)
California:
General geology:
*California Coast Range ultramafic rocks
E. H. Bailey (M)
Glaucophane schist terranes within the Franciscan formation
R. G. Coleman (M)
*San Andreas fault
L. F. Noble, Valyermo (Calif.)
*Ash Meadows quadrangle, California-Nevada
C. S. Denny (W)
*Big Maria Mountains quadrangle
W. B. Hamilton (D)
*Blanco Mountain quadrangle
C. A. Nelson (Los Angeles, Calif.)
*Petrology of the Burney area
G. A. Macdonald (Honolulu, Hawaii)
*Death Valley
C. B. Hunt (D)
*Funeral Peak quadrangle
H. D. Drewes (D)
*Independence quadrangle
D. C. Ross (M)
*Northern Klamath Mountains, Condrey Mountain quadrangle
P. E. Hotz (M)
*Merced Peak quadrangle
D. L. Peck (M)
*Mt. Pinchot quadrangle
J. G. Moore (M)
*Salinas Valley
D. L. Durham (M)
*Geology of San Nicolas Island
J. G. Vedder (M)
Glacial geology of the west central Sierra Nevada region
F. M. Fryxell (Rock Island, Ill.)
*Weaverville, French Gulch and Hayfork quadrangles, southern Klamath Mountains
W. P. Irwin (M)
Mineral resources:
Western oxidized zinc deposits
A. V. Heyl (W)
Geochemical halos of mineral deposits, California and Arizona
L. C. Huff (D)
Origin of the borate-bearing marsh deposits of California, Oregon, and Nevada (boron)
W. C. Smith (M)
*Furnace Creek area (boron)
J. F. McAllister (M)
*Western Mojave Desert (boron)
T. W. Dibblee, Jr. (M)
*Geology and origin of the saline deposits of Searles Lake (boron)
G. I. Smith (M)
*Bishop tungsten district
P. C. Bateman (M)

California—Continued
Mineral resources—Continued
*Geologic study of the Sierra Nevada batholith (tungsten, gold, base metals)
P. C. Bateman (M)
*Eastern Sierra tungsten area: Devil's Postpile, Mt. Morrison, and Casa Diablo quadrangles (tungsten, base metals)
C. D. Rinehart (M)
Structural geology of the Sierra foothills mineral belt (Copper, zinc, gold, chromite)
L. D. Clark (M)
*Mt. Diablo area (quicksilver, copper, gold, silver)
E. H. Pampeyan (M)
*New York Butte quadrangle (lead-zinc)
W. C. Smith (M)
*Panamint Butte quadrangle including special geochemical studies. (lead-silver)
W. E. Hall (W)
Lateritic nickel deposits of the Klamath Mountains, Oregon-California
P. E. Hotz (M)
*Eastern Los Angeles basin (petroleum)
J. E. Schoellhamer (M)
*Northwest Sacramento Valley (petroleum)
R. D. Brown, Jr. (M)
*Southeastern Ventura basin (petroleum)
E. L. Winterer (Los Angeles, Calif.)
Engineering Geology:
*Surficial geology of the Beverly Hills, Venice, and Topanga quadrangles, Los Angeles (urban geology)
J. T. McGill (Los Angeles, Calif.)
Malibu Beach quadrangle (urban geology)
R. F. Yerkes (M)
*Oakland East quadrangle (urban geology)
D. H. Radbruch (M)
*San Francisco Bay area, San Francisco North quadrangle (urban geology)
J. Schlocker (M)
*San Francisco Bay area, San Francisco South quadrangle (urban geology)
M. G. Bonilla (M)
Geophysical studies:
Great Basin geophysical studies
D. R. Mabey (M)
Gravity studies, California-Nevada region
D. J. Stuart (D)
Gravity studies, southern Cascade Mountains,
L. C. Pakiser (D)
Aerial radiological monitoring surveys, Los Angeles
K. G. Books (W)
Rocks and structures of the Los Angeles basin, and their gravitational effects
T. H. McCulloh (Riverside, Calif.)
Aerial radiological monitoring surveys, San Francisco
J. A. Pitkin (W)
Geophysical study in the Sierra Nevada Mountains
H. W. Oliver (W)
Gravity studies, Sierra Valley
W. H. Jackson (D)
Paleontology:
Foraminifera of the Lodo formation, central California
M. C. Israelsky (M)

California—Continued
Paleontology—Continued
Cenozoic Foraminifera, Colorado Desert
P. J. Smith (M)
Geology and paleontology of the Cuyama Valley area
J. G. Vedder (M)
Water resources:
Hydrologic effect of urbanization
A. O. Waananen (h, M)
North Pacific Coast area (surface water)
E. E. Harris (s, M)
Water loss and gain studies in California
W. C. Peterson (s, M)
Tidal flow measurement
S. E. Rantz (s, M)
California coastal basins hydrology
S. E. Rantz (s, M)
Floods from small areas in California
L. E. Young (s, M)
Clastic sedimentation in a bolson environment.
L. K. Lustig (q, Boston, Mass.)
Solute-solid relations in lacustrine closed basins of the alkali-carbonate type.
B. F. Jones (q, W)
A study of the occurrence and distribution of trace elements in fresh and saline waters.
W. D. Silvey (q, Sacramento, Calif.)
Processes affecting solute composition and minor element distribution in lacustrine closed basins.
B. F. Jones (q, W)
Mineral constituents in ground water
J. H. Feth (g, M)
Mechanics of aquifers
J. F. Poland (g, Sacramento, Calif.)
Agricultural Research Service soil-moisture study
R. E. Evenson (g, Sacramento, Calif.)
Lower Colorado River Basin hydrology
C. C. McDonald (g, Yuma, Ariz.)
Alameda Creek basin (pollution of surface waters)
R. T. Kiser (q, Sacramento, Calif.)
Cache Creek basin (sedimentation conditions)
George Porterfield (q, Sacramento, Calif.)
Camp Pendleton Marine Corps Base (ground water)
J. S. Bader (g, Sacramento, Calif.)
Dale Lake area (ground water)
G. M. Hogenson (g, Sacramento, Calif.)
Death Valley National Monument (ground water)
F. Kunkel (g, Sacramento, Calif.)
Ducor-Famoso area (ground water)
G. S. Hilton (g, Sacramento, Calif.)
Edwards Air Force Base (ground water)
W. R. Moyle (g, Sacramento, Calif.)
Fruitvale oil field (Quality of ground waters)
B. V. Salotto (q, Sacramento, Calif.)
Furnace Creek and Pinto Basin (ground water)
G. M. Hogenson (g, Sacramento, Calif.)
Hoopa Valley (ground water)
J. L. Poole (g, Sacramento, Calif.)
Inyokern Naval Ordnance Test Station (ground water)
F. Kunkel (g, Sacramento, Calif.)
Kaweah-Tule area (ground water)
M. G. Croft (g, Sacramento, Calif.)
Kern River fan (ground water)
R. H. Dale (g, Sacramento, Calif.)

California—Continued
Water resources—Continued
Lake Pillsbury sedimentation survey
George Porterfield (q, Sacramento, Calif.)
Lower Mojave area, west part (ground water)
G. M. Hogenson (g, Sacramento, Calif.)
Oak Mountain Air Force Facility (ground water)
G. A. Miller (g, Sacramento, Calif.)
Point Arguello (ground water)
R. E. Evenson (g, Sacramento, Calif.)
Point Mugu area (ground water)
R. W. Page (g, Sacramento, Calif.)
San Antonio Valley (ground water)
R. E. Evenson (g, Sacramento, Calif.)
Determination of evaporation coefficient for reservoirs in San Diego
G. E. Koberg (h, D)
San Francisco Bay barriers (ground water)
G. M. Hogenson (g, Sacramento, Calif.)
San Nicolas Island (ground water)
R. W. Page (g, Sacramento, Calif.)
Santa Barbara County (ground water)
R. E. Evenson (g, Sacramento, Calif.)
Santa Maria Valley (ground water)
R. E. Evenson (g, Sacramento, Calif.)
Sierra Ordnance Depot (ground water)
G. S. Hilton (g, Sacramento, Calif.)
South Coast basins (ground water)
R. E. Evenson (g, Sacramento, Calif.)
Stony Gorge Reservoir sedimentation survey
C. A. Dunnam (q, Sacramento, Calif.)
Tecolote Tunnel, California, effect on spring flow
S. E. Rantz (s, M)
Twentynine Palms Marine Corps Training Center (ground water)
H. B. Dyer (g, Sacramento, Calif.)
Colorado:
General geology:
Investigation of Jurassic stratigraphy, south-central Wyoming and northwestern Colorado
G. N. Pipiringos (D)
Upper Cretaceous stratigraphy, northwestern Colorado and northeastern Utah
A. D. Zapp (D)
Stratigraphy and paleontology of the Pierre shale, Front Range area, Colorado and Wyoming
W. A. Cobban and G. R. Scott (D)
Pennsylvanian and Permian stratigraphy, Rocky Mountain Front Range, Colorado and Wyoming
E. K. Maughan (D)
Petrology and geochemistry of the Laramide intrusives in the Colorado Front Range
G. Phair (W)
Significance of lead-alpha age variation in batholiths of the Colorado Front Range
D. Gottfried (W)
Petrology and geochemistry of the Boulder Creek batholith, Colorado Front Range
G. Phair (W)
Magmatic differention in calc-alkaline intrusives, Mt. Princeton area
P. Toulmin 3d (W)
*Mountain front area, east-central Front Range
D. M. Sheridan (D)

Colorado—Continued
General geology—Continued
Tuffs of the Green River formation
R. L. Griggs (D)
*Cameron Mountain quadrangle
M. G. Dings (D)
*Glenwood Springs quadrangle
N. W. Bass (D)
*Upper South Platte River, North Fork
G. R. Scott (D)
Mineral resources:
Western oxidized zinc deposits
A. V. Heyl (W)
*Lake George district (beryllium)
C. C. Hawley (D)
Volcanic and economic geology of the Creede caldera (base and precious metals; fluorspar)
T. A. Steven (D)
Ore deposition at Creede
E. W. Roedder (W)
*Central City-Georgetown area, including studies of the Precambrian history of the Front Range (base, precious, and radioactive metals)
P. K. Sims (D)
*Holy Cross quadrangle and the Colorado mineral belt (lead, zinc, silver, copper, gold)
O. Tweto (D)
*Minturn quadrangle (zinc, silver, copper, lead, gold)
T. S. Lovering (D)
*Rico district (lead, zinc, silver)
E. T. McKnight (W)
*San Juan mining area, including detailed study of the Silverton Caldera (lead, zinc, silver, gold, copper)
R. G. Luedke (W)
*Tenmile Range, including the Kokomo mining district (base and precious metals)
A. H. Koschmann (D)
*Poncha Springs and Saguache quadrangles (fluorspar)
R. E. Van Alstine (W)
*Powderhorn area, Gunnison County (thorium)
J. C. Olson (D)
*Wet Mountains (thorium, base and precious metals)
M. R. Brock (W)
Wallrock alteration and its relation to thorium deposition in the Wet Mountains
G. Phair (W)
*Uranium deposits in the Front Range
P. K. Sims (D)
**Compilation of Colorado Plateau geologic maps (uranium, vanadium)
D. G. Wyant (D)
Uranium-vanadium deposits in standstone, with emphasis on the Colorado Plateau
R. P. Fischer (D)
Relative concentrations of chemical elements in rocks and ore deposits of the Colorado Plateau (uranium, vanadium, copper)
A. T. Miesch (D)
Colorado Plateau botanical prospecting studies
F. J. Kleinhampl (M)
Clay studies, Colorado Plateau
L. G. Schultz (D)
Lithologic studies, Colorado Plateau
R. A. Cadigan (D)

Colorado—Continued
Mineral resources—Continued
Stratigraphic studies, Colorado Plateau (uranium, vanadium)
L. C. Craig (D)
Triassic stratigraphy and lithology of the Colorado Plateau (uranium, copper)
J. H. Stewart (D)
San Rafael group stratigraphy, Colorado Plateau (uranium)
J. C. Wright (D)
*Baggs area, Wyoming and Colorado (uranium)
G. E. Prichard (D)
*Bull Canyon district (vanadium, uranium)
C. H. Roach (D)
Exploration for uranium deposits in the Gypsum Valley district
C. F. Withington (W)
*Klondike Ridge area (uranium, copper, manganese, salines)
J. D. Vogel (D)
*La Sal area, Utah-Colorado (uranium, vanadium)
W. D. Carter (Santiago, Chile)
*Lisbon Valley area, Utah-Colorado (uranium, vanadium, copper)
G. W. Weir (M)
*Maybell-Lay area, Moffat County (uranium)
M. J. Bergin (W)
*Ralston Buttes (uranium)
D. M. Sheridan (D)
*Western San Juan Mountains (uranium, vanadium, gold)
A. L. Bush (W)
*Slick Rock district (uranium, vanadium)
D. R. Shawe (D)
Uravan district (vanadium, uranium)
R. L. Boardman (W)
*Ute Mountains (uranium, vanadium)
E. B. Ekren (D)
*Carbondale coal field
J. R. Donnell (D)
*Trinidad coal field
R. B. Johnson (D)
*Animas River area, Colorado and New Mexico (coal, oil, and gas)
H. Barnes (D)
*Eastern North Park (coal, oil, and gas)
D. M. Kinney (W)
*Western North Park (coal, oil, and gas)
W. J. Hail (D)
Subsurface geology of the Dakota sandstone, Colorado and Nebraska (oil and gas)
N. W. Bass (D)
**Oil shale investigations
D. C. Duncan (W)
*Grand-Battlement Mesa oil shale
J. R. Donnell (D)
Engineering geology and geophysical studies:
Gravity profile of the southern Rocky Mountains, Colorado
D. J. Stuart (D)
Colorado Plateau regional geophysical studies
H. R. Joesting (W)
*Air Force Academy (construction-site planning)
D. J. Varnes (D)

Colorado—Continued
Engineering geology and geophysical studies—Continued
Black Canyon of the Gunnison River (construction-site planning)
W. R. Hansen (D)
*Upper Green River valley (construction-site planning)
W. R. Hansen (D)
*Denver metropolitan area (urban geology)
R. M. Lindvall (D)
*Golden quadrangle (urban geology)
R. Van Horn (D)
*Morrison quadrangle (urban geology)
J. H. Smith (D)
*Pueblo and vicinity (urban geology)
G. R. Scott (D)
Engineering geology of the Roberts Tunnel
C. S. Robinson (D)
Water resources:
Characteristics of municipal water supplies in Colorado
E. A. Moulder (g, D)
Effects of exposure on slope morphology
R. F. Hadley (h, D)
Mechanics of hillslope erosion
S. A. Schumm (h, D)
Plant species or communities as indicators of soil moisture availability
F. A. Branson (h, D)
Effects of particle-size distribution on mechanics of flow in alluvial channels
D. B. Simons (q, Fort Collins, Colo.)
Effects of sediment characteristics on fluvial morphology hydraulics
S. A. Schumm (h, D)
Effects of grazing exclusion in Badger Wash area
G. C. Lusby (h, D)
Bent County (ground water)
J. H. Irwin (g, D)
Flood inundation, Boulder County
C. T. Jenkins (s, D)
Ogalalla formation, eastern Cheyenne and Kiowa Counties (ground water)
A. J. Boettcher (g, D)
Huerfano County (ground water)
T. G. McLaughlin (g, D)
Kit Carson County (ground water)
G. H. Chase (g, D)
Otero County and part of Crowley County (ground water)
W. G. Weist (g, D)
Prowers County (ground water)
P. T. Voegel (g, D)
Pueblo and Fremont Counties (ground water)
H. E. McGovern (g, D)
Washington County (ground water)
H. E. McGovern (g, D)
Yuma County (ground water)
W. G. Weist (g, D)
Big Sandy valley below Limon (ground water)
D. L. Coffin (g, D)
Cache La Poudre valley (ground water)
L. A. Hershey (g, D)
Colorado National Monument (general geology)
S. W. Lohman (g, D)
Denver Basin (ground water)
G. H. Chase (g, D)

Colorado—Continued
Water resources—Continued
Fountain and Jimmy Camp valleys (ground water)
E. D. Jenkins (g, D)
Grand Junction artesian area (ground water)
S. W. Lohman (g, D)
Fluvial sedimentation and runoff in Kiowa Creek
J. C. Mundorff (q, Lincoln, Nebr.)
Investigation of trap efficiencies of K–79 Reservoir, Kiowa Creek basin
J. C. Mundorff (q, Lincoln, Nebr.)
North and Middle Parks (ground water)
P. T. Voegel (g, D)
Rocky Mountain National Park (ground water)
D. L. Coffin (g, D)
Ute Mountain Ute Indian Reservation (ground water)
J. H. Irwin (g, D)
Connecticut:
General geology:
*Ansonia, Mount Carmel, and Southington quadrangles; bedrock geologic mapping
C. E. Fritts (D)
*Ashaway quadrangle, Rhode Island-Connecticut; bedrock geologic mapping
T. G. Feininger (Boston, Mass.)
*Ashaway and Watch Hills quadrangles, Connecticut-Rhode Island; surficial geologic mapping
J. P. Schafer (Boston, Mass.)
*Avon and New Hartford quadrangles
R. W. Schnabel (D)
*Bristol and New Britain quadrangles
H. E. Simpson (D)
*Broad Brook and Manchester; quadrangles surficial geologic mapping
R. B. Colton (D)
*Columbia, Fitchville, Norwich, Marlboro, and Willimantic quadrangles; bedrock geologic mapping
G. L. Snyder (D)
*Durham quadrangle; surficial geologic mapping
H. E. Simpson (D)
*Fitchville and Norwich quadrangles; surficial geologic mapping
P. M. Hanshaw (D)
*Hampton and Scotland quadrangles; bedrock geologic mapping
H. R. Dixon (D)
*Meriden quadrangle
P. M. Hanshaw (D)
*Montville, New London, Niantic, and Uncasville quadrangles
R. Goldsmith (D)
*Mystic and Old Mystic quadrangles; bedrock geologic mapping
R. Goldsmith (D)
*Springfield South quadrangle, Massachussets and Conneticut.
J. H. Hartshorn (Boston, Mass.)
*Tarrifville and Windsor Locks quadrangles; bedrock geologic mapping
R. W. Schnabel (D)
*Thompson quadrangle, Connecticut-Rhode Island
P. M. Hanshaw (Boston, Mass.)
*Watch Hill quadrangle, Connecticut-Rhode Island; bedrock geologic mapping
G. E. Moore, Jr. (Columbus, Ohio)

Connecticut—Continued
General geology—Continued
*Stratigraphy and structure of Taconic rocks
E-an Zen (W)
Water resources:
Recognition of late glacial substages in New England and New York
J. E. Upson (g, Mineola, N.Y.)
North-central Connecticut (ground water)
R. V. Cushman (g, Middletown, Conn.)
Bristol-Plainville-Southington area (ground water)
A. M. LaSala, Jr. (g, Middletown, Conn.)
Farmington-Granby area (ground water)
A. D. Randall (g, Middletown, Conn.)
Hartford North Quadrangle
R. V. Cushman (g, Middletown, Conn.)
Ground-water salinity and pumpage in New Haven
R. V. Cushman (g, Middletown, Conn.)
Lower Quinebaug basin (ground water)
A. D. Randall (g, Middletown, Conn.)
Lower Quinnipiac and Mill River lowlands (ground water)
A. M. LaSala, Jr. (g, Middletown, Conn.)
Tariffville quadrangle (Surficial geology)
A. D. Randall (g, Middletown, Conn.)
Voluntown quadrangle (ground water)
K. E. Johnson (g, Providence, R.I.)
Waterbury-Bristol area (ground water)
R. V. Cushman (g, Middletown, Conn.)
Watch Hill quadrangle (ground water)
K. E. Johnson (g, Providence, R.I.)

Delaware:
Water-table and engineering mapping
D. H. Boggess (g, Newark, Del.)
Salinity conditions of Lower Delaware River basin
D. McCartney (q, Philadelphia, Pa.)
Salt-water encroachment in the Lewes-Rehoboth area
D. R. Rima (g, Newark, Del.)
New Castle County (ground water)
D. R. Rima (g, Newark, Del.)
Newark area (ground water)
D. R. Rima (g, Newark, Del.)
Red Clay Valley (ground water)
D. H. Boggess (g, Newark, Del.)

Florida:
Subsurface Paleozoic rocks of Florida
J. M. Berdan (W)
Mesozoic rocks of Florida and eastern Gulf Coast
P. L. Applin (Jackson, Miss.)
*Land-pebble phosphate deposits
J. B. Cathcart (D)
Phosphate deposits of northern Florida
G. H. Espenshade (W)
Artesian water in Tertiary limestones in Florida, southern Georgia, and adjacent parts of Alabama and South Carolina
V. T. Stringfield (w, W)
Drought of 1954–56 in Florida
R. W. Pride (s, Ocala, Fla.)
Physical characteristics of selected Florida lakes
W. E. Kenner (s, Ocala, Fla.)
Bridge-site studies, Florida (surface water)
R. W. Pride (s, Ocala, Fla.)
Mechanics of diffusion, fresh and salt water
H. H. Cooper (g, Tallahassee, Fla.)

Florida—Continued
Alachua, Bradford, Clay, and Union Counties (water resources)
W. E. Clark (g, Tallahassee, Fla.)
Northeastern Broward County (ground water)
G. R. Tarver (g, Tallahassee, Fla.)
Central Broward County (ground water)
H. Klein (g, Tallahassee, Fla.)
Collier County (ground water)
H. J. McCoy (g, Tallahassee, Fla.)
Salt-water encroachment studies in Dade County
H. Klein (g, Tallahassee, Fla.)
Area B, Dade County (ground water)
C. B. Sherwood (g, Tallahassee, Fla.)
Duval, Nassau, and Baker Counties (ground water)
Tarver, G. (g, Tallahassee, Fla.)
Escambia and Santa Rosa Counties, Florida (water)
R. H. Musgrove (s, Ocala, Fla.)
Glades and Hendry Counties (ground water)
W. F. Lichter (g, Tallahassee, Fla.)
Orange County (water resources)
W. F. Lichter (g, Tallahassee, Fla.)
Polk County (ground water)
H. G. Stewart (g, Tallahassee, Fla.)
Polk County (surface water)
R. C. Heath (s, Ocala, Fla.)
St. Johns, Flagler, and Putnam Counties (ground water)
D. W. Brown (g, Tallahassee, Fla.)
St. Johns, Flagler, and Putnam Counties, Florida (surface water)
W. E. Kenner (s, Ocala, Fla.)
Everglades National Park (water)
J. H. Hartwell (s, Ocala, Fla.)
Green Swamp area, Florida (water)
R. W. Pride (s, Ocala, Fla.)
Hillsborough River floods of 1960
R. W. Pride (s, Ocala, Fla.)
Snake Creek Canal salinity study
F. A. Kohout (g, Tallahassee, Fla.)
Snapper Creek, Snake Creek, and Levee 30 studies (ground water)
C. B. Sherwood (g, Tallahassee, Fla.)
Tampa Bay area (water resources)
Grantham, R. (q, Ocala, Fla.)

Georgia:
Clinton iron ores of the southern Appalachians
R. P. Sheldon (D)
Mesozoic rocks of Florida and eastern Gulf Coast
P. L. Applin (Jackson, Miss.)
Pre-Selma Cretaceous rocks of Alabama and adjacent States
L. C. Conant (Tripoli, Libya)
Aerial radiological monitoring surveys, Georgia Nuclear Aircraft Laboratory
J. A. MacKallor (W)
Aerial radiological monitoring surveys, Savannah River Plant, Georgia and South Carolina
R. G. Schmidt (W)
River systems studies
M. T. Thomson (S, Atlanta, Ga.)
Relation of geology to low flow
O. J. Cosner (s, Atlanta, Ga.)
Low-flow studies
R. F. Carter (s, Atlanta, Ga.)

Georgia—Continued
Bridge-sites studies (surface water)
C. M. Bunch (s, Atlanta, Ga.)
Areal flood studies
C. M. Bunch (s, Atlanta, Ga.)
Flood gaging
C. M. Bunch (s, Atlanta, Ga.)
Artesian water in Tertiary limestones in Florida, southern Georgia and adjacent parts of Alabama and South Carolina
V. T. Stringfield (w, W)
Solution subsidence of a limestone terrane in southwest Georgia
S. M. Herrick (g, Atlanta, Ga.)
Stratigraphy of the Trent marl and related units
P. M. Brown (g, Raleigh, N.C.)
Paleozoic rock area, Bartow County
M. G. Croft (g, Atlanta, Ga.)
Paleozoic rock area, Chatooga County (ground water)
C. W. Cressler (g, Atlanta, Ga.)
Georgia crystalline rock area, Dawson County (ground water)
C. W. Sever (g, Atlanta, Ga.)
Lee and Sumter Counties (ground water)
V. Owen (g, Atlanta, Ga.)
Mitchell County (ground water)
V. Owen (g, Atlanta, Ga.)
Seminole, Decatur, and Grady Counties (ground water)
V. Owen (g, Atlanta, Ga.)
Paleozoic rock area, Walker County (ground water)
C. W. Cressler (g, Atlanta, Ga.)
Salt-water encroachment in the Brunswick area
R. L. Wait (g, Atlanta, Ga.)
Georgia Nuclear Laboratory area (ground water)
J. W. Stewart (g, Atlanta, Ga.)
Macon area (ground water)
H. E. LeGrand (w, W)
Salt-water encroachment in the Savannah area
H. B. Counts (g, Atlanta, Ga.)

Hawaii:
Geological, geochemical and geophysical studies of Hawaiian volcanology
J. P. Eaton (Hawaii)
Hawaiian volcanoes, thermal and magnetic studies
J. H. Swartz (W)
High-alumina weathered basalt on Kauai, Hawaii
S. H. Patterson (W)
Low-flow studies
G. T. Hirashima (s, Honolulu, Hawaii)
Windward Oahu (ground water)
K. J. Takasaki (g, Honolulu, Hawaii)
Central and southern Oahu (ground water)
F. N. Visher (g, Honolulu, Hawaii)
Mokuleia-Waialua area, Oahu (ground water)
D. A. Davis (g, Honolulu, Hawaii)
Waianae district, Oahu (ground water)
F. N. Visher (g, Honolulu, Hawaii)

Idaho:
General geology:
**South Central Idaho
C. P. Ross (D)
**Geologic mapping of the Spokane-Wallace region, Washington-Idaho
A. B. Griggs (M)

Idaho—Continued
General geology—Continued
*Big Creek quadrangle
B. F. Leonard (D)
*Geochemistry and metamorphism of the Belt Series, Clark Fork and Packsaddle Mountain quadrangles; Idaho and Montana
J. E. Harrison (D)
*Leadore, Gilmore, and Patterson quadrangles
E. T. Ruppel (D)
**Mackay quadrangle
C. P. Ross (D)
*Metamorphism of the Orofino area
A. Hietanen (M)
*Owyhee and Mt. City quadrangles, Nevada-Idaho
R. R. Coats (M)
*Riggins quadrangle
W. B. Hamilton (D)
**Regional geology and structure of the central Snake River plain
H. A. Powers (D)
*Snake River Valley, American Falls region
D. E. Trimble (D)
*Snake River valley, western region
H. A. Powers (D)
Petrology of volcanic rocks, Snake River valley
H. A. Powers (D)
*Yellow Pine quadrangle
B. F. Leonard (D)
Mineral resources:
*Greenacres quadrangle, Washington-Idaho (high-alumina clays)
P. L. Weis (Spokane, Wash.)
*Blackbird Mountain area (cobalt)
J. S. Vhay (Spokane, Wash.)
*General geology of the Coeur d'Alene mining district (lead, zinc, silver)
A. B. Griggs (M)
Ore deposits of the Coeur d'Alene mining district (lead, zinc, silver)
V. C. Fryklund, Jr. (Spokane, Wash.)
*Thunder Mountain niobium area, Montana-Idaho
R. L. Parker (D)
Stratigraphy and resources of the Phosphoria formation (phosphate, minor elements)
V. E. McKelvey (W)
*Aspen Range-Dry Ridge area (phosphate)
V. E. McKelvey (W)
*Soda Springs quadrangle, including studies of the Bannock thrust zone (phosphate)
F. C. Armstrong (Spokane, Wash.)
*Radioactive placer deposits of central Idaho
D. L. Schmidt (Seattle, Wash.)
Geophysical studies:
Pacific Northwest geophysical studies
W. E. Davis (W)
Gravity studies, Snake River Plain
D. J. Stuart (D)
Gravity studies, Yellowstone area
H. L. Baldwin (D)
Aerial radiological monitoring surveys, National Reactor Testing Station
R. G. Bates (W)

Idaho—Continued
Water resources:
Use of tritium in hydrologic studies
C. W. Carlston (g, W)
Aberdeen-Springfield area (ground water)
H. G. Sisco (g, Boise, Idaho)
American Falls Reservoir (ground water)
M. J. Mundorff (g, Boise, Idaho)
Artesian City area (ground water)
E. G. Crosthwaite (g, Boise, Idaho)
Dry Creek area (ground water)
E. G. Crothwaite (g, Boise, Idaho)
Little Lost River basin (water resources)
M. J. Mundorff (g, Boise, Idaho)
Mud Lake Basin (ground water)
P. R. Stevens (g, Boise, Idaho)
Geology, hydrology, and waste disposal at the National Reactor Testing Station
R. L. Nace (w, W)
Hydrology of subsurface waste disposal, National Reactor Testing Station
P. H. Jones (g, Boise, Idaho)
Research on hydrology, National Reactor Testing Station
E. H. Walker (g, Boise, Idaho)
Salmon Falls creek area (ground water)
E. G. Crosthwaite (g, Boise, Idaho)
Feasibility of artificial recharge of the Snake Plain aquifer
M. J. Mundorff (g, Boise, Idaho)
Spokane River Valley (ground water)
M. J. Mundorff (g, Boise, Idaho)

Illinois:
Geologic development of the Ohio River valley
L. L. Ray (W)
Lower Pennsylvanian floras of Illinois and adjacent States
C. B. Read (Albuquerque, N. Mex.)
*Stratigraphy of the lead-zinc district near Dubuque
J. W. Whitlow (W)
*Wisconsin zinc-lead mining district
J. W. Whitlow (D)
Floods from small areas
W. D. Mitchell (s, Champaign, Ill.)
Low-flow frequency on Illinois streams
W. D. Mitchell (s, Champaign, Ill.)
Bridge-site studies (surface water)
W. D. Mitchell (s, Champaign, Ill.)

Indiana:
Geologic development of the Ohio River valley
L. L. Ray (W)
Lower Pennsylvanian floras of Illinois and adjacent States
C. B. Read (Albuquerque, N. Mex.)
*Quaternary geology of the Owensboro quadrangle, Kentucky-Indiana
L. L. Ray (W)
Lake mapping and stabilization (surface water)
D. C. Perkins (s, Indianapolis, Ind.)
Low-flow characteristics
R. E. Hoggatt (s, Indianapolis, Ind.)
Northwestern Indiana (ground water)
J. S. Rosenshein (g, Indianapolis, Ind.)
Southeastern Indiana (ground water)
J. S. Rosenshein (g, Indianapolis, Ind.)

Indiana—Continued
West-central Indiana (ground water)
F. A. Watkins (g, Indianapolis, Ind.)
Adams County (ground water)
F. A. Watkins (g, Indianapolis, Ind.)
Clay, Greene, Owen, Sullivan, and Vigo Counties (ground water)
F. A. Watkins (g, Indianapolis, Ind.)
Fountain, Montgomery, Parke, Putnam, and Vermillion Counties (ground water)
F. A. Watkins (g, Indianapolis, Ind.)
Bunker Hill Air Force Base (ground water)
F. A. Watkins (g, Indianapolis, Ind.)

Iowa:
Lower Pennsylvanian floras of Illinois and adjacent States
C. B. Read (Albuquerque, N. Mex.)
*Stratigraphy of the lead-zinc district near Dubuque
J. W. Whitlow (W)
*Omaha-Council Bluffs and vicinity, Nebraska and Iowa (urban geology)
R. D. Miller (D)
*Wisconsin zinc-lead mining district
J. W. Whitlow (D)
Low-flow frequency studies
H. H. Schwob (s, Iowa City, Iowa)
Channel geometry studies (surface water)
H. H. Schwob (s, Iowa City, Iowa)
Flood profiles
H. H. Schwob (s, Iowa City, Iowa)
Floods from small areas
H. H. Schwob (s, Iowa City, Iowa)
The Mississippian Aquifer of Iowa
W. L. Steinhilber (g, Iowa City, Iowa)
Cerro Gordo County (ground water)
W. L. Steinhilber (g, Iowa City, Iowa)
Linn County (ground water)
R. E. Hansen (g, Iowa City, Iowa)

Kansas:
Trace elements in rocks of Pennsylvanian age, Oklahoma, Kansas, Missouri (uranium, phosphate)
W. Danilchik (Quetta, Pakistan)
Tri-State lead-zinc district, Oklahoma, Missouri, Kansas
E. T. McKnight (W)
Paleozoic stratigraphy of the Sedgwick Basin (oil and gas)
W. L. Adkison (Lawrence, Kans.)
*Shawnee County (oil and gas)
W. D. Johnson, Jr. (Lawrence, Kans.)
*Wilson County (oil and gas)
H. C. Wagner (M)
Brown County (ground water)
C. K. Bayne (g, Lawrence, Kans.)
Cowley County (ground water)
C. K. Bayne (g, Lawrence, Kans.)
Finney, Kearny, and Hamilton Counties (ground water)
S. W. Fader (g, Lawrence, Kans.)
Grant and Stanton Counties (ground water)
S. W. Fader (g, Lawrence, Kans.)
Johnson County (ground water)
H. G. O'Connor (g, Lawrence, Kans.)
Linn County (ground water)
W. J. Jungman (g, Lawrence, Kans.)
Miami County (ground water)
D. M. Miller (g, Lawrence, Kans.)

Kansas—Continued
- Montgomery County (ground water)
  - H. G. O'Connor (g, Lawrence, Kans.)
- Neosho County (ground water)
  - W. J. Jungman (g, Lawrence, Kans.)
- Pratt County (ground water)
  - C. W. Lane (g, Lawrence, Kans.)
- Rush County (ground water)
  - J. McNellis (g, Lawrence, Kans.)
- Sedgwick County (ground water)
  - C. W. Lane (g, Lawrence, Kans.)
- Trego County (ground water)
  - W. G. Hodson (g, Lawrence, Kans.)
- Wallace County (ground water)
  - W. G. Hodson (g, Lawrence, Kans.)
- The effects of sediment characteristics on fluvial morphology hydraulics
  - S. A. Schumm (h, D)
- Southwestern Kansas (ground water)
  - S. W. Fader (g, Lawrence, Kans.)
- Northwestern Kansas (ground water)
  - S. W. Fader (g, Lawrence, Kans.)
- Ground water-surface water interrelations
  - L. W. Furness (s, Topeka, Kans.)
- Flood investigations
  - L. W. Furness (s, Topeka, Kans.)
- Sedimentation in the Little Arkansas River basin
  - J. C. Mundorff (q, Lincoln, Nebr.)
- Fluvial sediment in the Lower Kansas River basin
  - J. C. Mundorff (q, Lincoln, Nebr.)
- Chemical quality of surface waters and sedimentation in the Saline River drainage basin
  - P. R. Jordan (q, Lincoln, Nebr.)
- Flood-inundation mapping, Wichita
  - D. W. Ellis (s, Topeka, Kans.)
- Emergency water supplies in the Wichita area
  - C. W. Lane (g, Lawrence, Kansas)

Kentucky:
- *Geology of the southern Appalachian folded belt, Kentucky, Tennessee and Virginia
  - L. D. Harris (W)
- *Geologic mapping in Kentucky
  - P. W. Richards (Lexington, Ky.)
- Geologic development of the Ohio River valley
  - L. L. Ray (W)
- Clay deposits of the Olive Hill bed of eastern Kentucky
  - J. W. Hosterman (W)
- *Eastern Kentucky coal investigations
  - J. W. Huddle (W)
- Fluorspar deposits of northwestern Kentucky
  - R. D. Trace (Princeton, Ky.)
- *Salem quadrangle (fluorspar)
  - R. D. Trace (W)
- Vertebrate paleontology, Big Bone Lick
  - F. C. Whitmore, Jr. (Princeton, Ky.)
- Mammoth Cave
  - W. E. Davies (W)
- *Quaternary geology of the Owensboro quadrangle, Kentucky-Indiana
  - L. L. Ray (W)
- Aeromagnetic studies, Middlesboro-Morristown area, Tennessee-Kentucky-Virginia
  - R. W. Johnson, Jr. (Knoxville, Tenn.)

Kentucky—Continued
- Aerial radiological monitoring surveys, Oak Ridge National Laboratory
  - R. G. Bates (W)
- Hydrology of large springs in Kentucky
  - T. W. Lambert (g, Louisville, Ky.)
- Public and industrial water supplies of Kentucky
  - H. T. Hopkins (g, Louisville, Ky.)
- Geochemistry of natural waters of Kentucky
  - G. E. Hendrickson (g, Louisville, Ky.)
- Flood-frequency study
  - J. A. McCabe (s, Louisville, Ky.)
- Bridge-site studies (surface water)
  - C. H. Hannum (s, Louisville, Ky.)
- Low-flow frequency and flow duration
  - G. A. Kirkpatrick (s, Louisville, Ky.)
- Drainage-area compilation
  - H. C. Beaber (s, Louisville, Ky.)
- Rainfall-runoff relations
  - J. A. McCabe (s, Louisville, Ky.)
- Eastern Kentucky (surface water)
  - G. A. Kirkpatrick (s, Louisville, Ky.)
- Alluvial terraces of the Ohio River (ground water)
  - W. E. Price (g, Louisville, Ky.)
- Study of the hydrologic and related effects of strip mining in Beaver Creek watershed
  - J. J. Musser (q, Columbus, Ohio)
- Jackson Purchase area (ground water)
  - L. M. MacCary (g, Louisville, Ky.)
- Louisville area (ground water)
  - E. A. Bell (g, Louisville, Ky.)
- Mammoth Cave area (water resources)
  - G. E. Hendrickson (g, Louisville, Ky.)

Louisiana:
- Public water supplies in Louisiana
  - J. L. Snider (g, Baton Rouge, La.)
- Southeastern Louisiana (ground water)
  - M. D. Winner (g, Baton Rouge, La.)
- Southwestern Louisiana (ground water)
  - A. H. Harder (g, Baton Rouge, La.)
- Flood investigations
  - L. V. Page (s, Baton Rouge, La.)
- Ponds as runoff measuring devices
  - R. Sloss (s, Baton Rouge, La.)
- Bossier and Caddo Parishes (ground water)
  - H. C. May (g, Baton Rouge, La.)
- East and West Feliciana Parishes (ground water)
  - C. O. Morgan (g, Baton Rouge, La.)
- Natchitoches Parish (ground water)
  - R. Newcome (g, Baton Rouge, La.)
- Rapides Parish (ground water)
  - R. Newcome (g, Baton Rouge, La.)
- Red River Parish (ground water)
  - R. Newcome (g, Baton Rouge, La.)
- Sabine Parish (ground water)
  - R. Newcome (g, Baton Rouge, La.)
- Vernon Parish (ground water)
  - J. E. Rogers (g, Baton Rouge, La.)
- Baton Rouge-New Orleans valley area (ground water)
  - G. T. Cardwell (g, Baton Rouge, La.)
- Baton Rouge area (ground water)
  - C. O. Morgan (g, Baton Rouge, La.)
- Trap efficiency of reservoir on Bayou Dupont watershed
  - S. F. Kapustka (q, Baton Rouge, La.)

Louisiana—Continued
Ouachita River basin (quality of surface waters)
D. E. Everette (q, Baton Rouge, La.)
Tallulah area (ground water)
A. N. Turcan, Jr. (g, Baton Rouge, La.)
Maine:
*Attean quadrangle
A. L. Albee (Pasadena, Calif.)
*Bedrock geology of the Danforth, Forest, and Vanceboro quadrangles
D. M. Larrabee (W)
*Greenville quadrangle
G. H. Espenshade (W)
*The Forks quadrangle
F. C. Canney and E. V. Post (D)
*Southeastern Aroostook County (manganese)
L. Pavlides (W)
Aeromagnetic surveys
J. W. Allingham (W)
Gravity studies, northern Maine
M. F. Kane (W)
*Electromagnetic and geologic mapping in Island Falls quadrangle
F. C. Frischknecht (D)
*Geophysical and geologic mapping in the Stratton quadrangle
A. Griscom (W)
Coastal area of southwestern Maine (ground water)
G. C. Prescott (g, Augusta, Maine)
Maryland:
*Potomac Basin studies, Maryland, Virginia, and West Virginia
J. T. Hack (W)
Clay deposits
M. M. Knechtel (W)
*Allegany County (coal)
W. de Witt, Jr. (W)
Aerial radiological monitoring surveys, Belvoir area, Virginia and Maryland
S. K. Neuschel (W)
*Correlation of aeromagnetic studies and areal geology, Montgomery County
A. Griscom (W)
Airborne radioactivity and environmental studies, Washington County
R. M. Moxham (W)
Low-flow analyses
J. W. Odell ((s, College Park, Md.)
Effect of urbanization on peak discharge
R. W. Carter (s, W)
Changes below dams
M. G. Wolman (h, Baltimore, Md.)
Laboratory study of the growth of meanders in open channels
M. G. Wolman (h, Baltimore, Md.)
Potomac River basin
P. M. Johnston (g, W)
Allegany and Washington Counties (ground water)
T. H. Slaughter (g, Baltimore, Md.)
Anne Arundel County (ground water)
F. K. Mack (g, Baltimore, Md.)
Charles County (ground water)
T. H. Slaughter (g, Baltimore, Md.)

Maryland—Continued
Northern and western Montgomery County (ground water)
P. M. Johnston (g, Baltimore, Md.)
Fort George G. Meade (ground water)
E. G. Otton (g, Baltimore, Md.)
Sharpsburg area (ground water)
E. G. Otton (g, Baltimore, Md.)
Massachusetts:
Research and application of geology and seismology to Public Works planning
L. R. Page (Boston, Mass.)
Central Cape Cod, subsurface studies
L. W. Currier (W)
Sea-cliff erosion studies
C. A. Kaye (Boston, Mass.)
*Stratigraphy and structure of Taconic rocks
E-an Zen (W)
Vertebrate faunas, Martha's Vineyard
F. C. Whitmore, Jr. (W)
*Assawompsett Pond quadrangle
C. Koteff (Boston, Mass.)
*Athol quadrangle
D. F. Eschman (Ann Arbor, Mich.)
*Ayer quadrangle; bedrock geologic mapping
R. H. Jahns (University Park, Pa.)
*Billerica, Lowell, Tyngsboro, and Westford quadrangles
R. H. Jahns (University Park, Pa.)
*Blue Hills quadrangle
N. E. Chute (Syracuse, N.Y.)
*Clinton and Shrewsbury quadrangles; bedrock geologic mapping
R. F. Novotny (Boston, Mass.)
*Concord and Georgetown quadrangles
N. P. Cuppels (Boston, Mass.)
*Duxbury and Scituate quadrangles, surficial geologic mapping
N. E. Chute (Syracuse, N.Y.)
*Greenfield quadrangle; surficial geologic mapping
R. H. Jahns (University Park, Pa.)
*Lawrence, Reading, South Groveland, and Wilmington quadrangles; bedrock geologic mapping
R. O. Castle (Los Angeles, Calif.)
*North Adams quadrangle; bedrock geologic mapping
N. Herz (Belo Horizonte, Brazil)
*Norwood quadrangle
N. E. Chute (Syracuse, N.Y.)
*Reading and Salem quadrangles; surficial geologic mapping
R. N. Oldale (Boston, Mass.)
*Salem quadrangle; bedrock geologic mapping
P. Toulmin, III (W)
*Springfield south quadrangle
J. H. Hartshorn and C. Kotoff (Boston, Mass.)
*Taunton quadrangle; surficial geologic mapping
J. H. Hartshorn (Boston, Mass.)
Low-flow characteristics
G. K. Wood (s, Boston, Mass.)
Southeastern Massachusetts (ground water)
O. M. Hackett (g, Boston, Mass.)
Western Massachusetts (ground water)
O. M. Hackett (g, Boston, Mass.)
Southern Plymouth County (ground water)
J. M. Weigle (g, Boston, Mass.)
Brockton-Pembroke area (ground water)
R. G. Petersen (g, Boston, Mass.)

Massachusetts—Continued
- Cadwell Brook, Massachusetts (surface water)
  - G. K. Wood (s, Boston, Mass.)
- Analysis of surface water-ground water relationships in Hop Brook Basin
  - J. C. Kammerer (h, Boston, Mass.)
- Ipswich River drainage basin (ground water)
  - J. A. Baker (g, Boston, Mass.)
- Lowell area (ground water)
  - O. M. Hackett (g, Boston, Mass.)
- Lower Merrimack valley (ground water)
  - J. A. Baker (g, Boston, Mass.)
- Parker and Rowley River drainage basins (ground water)
  - J. A. Baker (g, Boston, Mass.)
- Wilmington-Reading area (ground water)
  - O. M. Hackett (g, Boston, Mass.)

Michigan:
- Geology of the Michigan Basin with reference to disposal of high-level radioactive wastes
  - W. deWitt (W)
- *Lake Algonquin drainage
  - J. T. Hack (W)
- *Michigan copper district
  - W. S. White (W)
- *Southern Dickinson County (iron)
  - R. W. Bayley (M)
- *Eastern Iron County (iron)
  - K. L. Wier (Iron Mountain, Mich.)
- *East Marquette district (iron)
  - J. E. Gair (D)
- *Iron River-Crystal Falls district (iron)
  - H. L. James (M)
- Geophysical studies in the Lake Superior region
  - G. D. Bath (M)
- Areal low-flow study
  - R. L. Knutilla and J. B. Miller (s, Lansing, Mich.)
- Alger County (ground water)
  - K. S. Vanlier (g, Lansing, Mich.)
- Battle Creek area (ground water)
  - M. Deutsch (g, Lansing, Mich.)
- North Branch Clinton River basin (surface water)
  - S. W. Wiitala (s, Lansing, Mich.)
- Elsie area (ground water)
  - K. E. Vanlier (g, Lansing, Mich.)
- Artificial recharge at Kalamazoo
  - J. E. Reed (g, Lansing, Mich.)
- Rifle River basin, Michigan (surface water)
  - R. W. Larson (s, Grayling, Mich.)
- Sloan and Deer Creek basins (surface water)
  - L. E. Stoimenoff (s, Lansing, Mich.)

Minnesota:
- *Cuyuna North range (iron)
  - R. G. Schmidt (W)
- Geophysical studies in the Lake Superior region
  - G. D. Bath (M)
- Flood-frequency analysis
  - C. H. Prior (s, St. Paul, Minn.)
- Clay County (ground water)
  - R. H. Brown (g, St. Paul, Minn.)
- Kittson, Marshall, and Roseau Counties (ground water)
  - G. R. Schiner (g, St. Paul, Minn.)
- Nobles County and part of Jackson County (ground water)
  - R. F. Norvitch (g, St. Paul. Minn.)

Minnesota—Continued
- Water resources in the vicinity of municipalities in the Mesabi Range area
  - R. D. Cotter (g, St. Paul, Minn.)
- Bedrock topography of the eastern Mesabi Range area, St. Louis County
  - E. L. Oakes (g, St. Paul, Minn.)
- Aurora area (ground water)
  - R. W. Maclay (g, St. Paul, Minn.)
- Chisholm area and Balkan Township, St. Louis County (ground water)
  - R. F. Norvitch (g, St. Paul, Minn.)
- Duluth Air Force Base (ground water)
  - J. E. Rogers (g, St. Paul, Minn.)
- Hibbing area (ground water)
  - R. F. Norvitch (g, St. Paul, Minn.)
- Mountain Iron-Virginia area (ground water)
  - R. D. Cotter (g, St. Paul, Minn.)
- Redwood Falls area (ground water)
  - G. R. Schiner (g, St. Paul, Minn.)

Mississippi:
- Oligocene gastropods and pelecypods
  - F. S. MacNeil (M)
- Mesozoic rocks of Florida and eastern Gulf Coast
  - P. L. Applin (Jackson, Miss.)
- Pre-Selma Cretaceous rocks of Alabama and adjacent States
  - L. C. Conant (Tripoli, Libya)
- Geologic and hydrologic environment of Tatum salt dome (test-site evaluation)
  - W. S. Twenhofel (D)
- Drainage area determination
  - J. D. Shell (s, Jackson, Miss.)
- Flood-frequency analysis
  - K. V. Wilson (s, Jackson, Miss.)
- Floods from small basins
  - K. V. Wilson (s, Jackson, Miss.)
- Bridge-site studies (surface water)
  - K. V. Wilson (s, Jackson, Miss.)
- Low-flow characteristics
  - H. G. Golden (s, Jackson, Miss.)
- Salt-water encroachment along the Mississippi Gulf Coast
  - J. W. Lang (g, Jackson, Miss.)
- Southwestern Mississippi (water resources)
  - E. J. Harvey (g, Jackson, Miss.)
- Cretaceous aquifers in Mississippi
  - J. W. Lang (g, Jackson, Miss.)
- Delta area (ground water)
  - B. E. Wasson (g, Jackson, Miss.)
- Jackson area (ground water)
  - E. J. Harvey (g, Jackson, Miss.)
- Pascagoula River basin (ground water)
  - E. J. Harvey (g, Jackson, Miss.)
- Pearl River basin (ground water)
  - B. E. Ellison (g, Jackson, Miss.)

Missouri:
- *Lead deposits of southeastern Missouri
  - T. H. Kiilsgaard (W)
- Tri-State lead-zinc district, Oklahoma, Missouri, Kansas
  - E. T. McKnight (W)
- Trace elements in rocks of Pennsylvanian age, Oklahoma, Kansas, Missouri (uranium, phosphate)
  - W. Danilchik (Quetta, Pakistan)

Missouri—Continued
Aeromagnetic studies in the Newport, Arkansas, and Ozark bauxite areas
A. Jesperson (W)
Correlation of aeromagnetic studies and areal geology, southeast Missouri
J. W. Allingham (W)
Flood investigations in small areas
E. H. Sandhaus (s, Rolla, Mo.)
Transportation of sediment by the Mississippi River
P. R. Jordan (q, Lincoln, Nebr.)

Montana:
General geology:
Chemical and physical properties of the Pierre shale, Montana, North Dakota, South Dakota, Wyoming, and Nebraska
H. A. Tourtelot (D)
Carbonatite deposits
W. T. Pecora (W)
Mesozoic stratigraphic paleontology of northwestern Montana
W. A. Cobban (D)
*Alice Dome—Sumatra area
H. R. Smith (D)
*Petrology of the Bearpaw Mountains
W. T. Pecora (W)
*Geochemistry and metamorphism of the Belt Series; Clark Fork and Packsaddle Mountain quadrangles, Idaho and Montana
J. E. Harrison (D)
*Big Sandy Creek area
R. M. Lindvall (D)
*Quaternary geology of the Browning area and the east slope of Glacier National Park
G. M. Richmond (D)
*Duck Creek Pass quadrangle
W. H. Nelson (D)
*South Gallatin Range
I. J. Witkind (D)
*Gravelly Range-Madison Range
J. B. Hadley (D)
Earthquake investigations, Hebgen Lake
J. B. Hadley (W) and I. J. Witkind (D)
*Maudlow quadrangle
B. Skipp (D)
Petrology and chromite resources of the Stillwater ultramafic complex
E. D. Jackson (M)
*Sun River Canyon area
M. R. Mudge (D)
*Three Forks quadrangle
G. D. Robinson (D)
*Toston quadrangle
G. D. Robinson (D)
*Willis quadrangle
W. B. Myers (D)
*Petrology of the Wolf Creek area
R. G. Schmidt (W)
Mineral resources:
Ore deposits of southwestern Montana
H. L. James (M)
Phosphate deposits of south-central Montana
R. W. Swanson (Spokane, Wash.)

Montana—Continued
Mineral resources—Continued
*Boulder batholith area (base, precious, and radioactive metals)
M. R. Klepper (W)
*General geology of the Coeur d'Alene mining district (lead, zinc, silver)
A. B. Griggs (M)
Ore deposits of the Coeur d'Alene mining district (lead, zinc, silver)
V. C. Fryklund, Jr. (Spokane, Wash.)
Manganese deposits of the Philipsburg area (manganese and base metals)
W. C. Prinz (W)
*Thunder Mountain niobium area, Montana-Idaho
R. L. Parker (D)
Williston Basin oil and gas studies, Wyoming, Montana, North Dakota, and South Dakota
C. A. Sandberg (D)
*Geology of the Winnett-Mosby area (oil and gas)
W. D. Johnson, Jr. (Lawrence, Kans.)
*Geology of the Livingston-Trail Creek area (coal)
A. E. Roberts (D)
Engineering geology:
Geology of the Williston Basin with reference to the disposal of high-level radioactive wastes
C. A. Sandberg (D)
*Fort Peck area (construction-site planning)
H. D. Varnes (D)
*Great Falls area, Montana (urban geology and construction-site planning)
R. W. Lemke (D)
*Wolf Point area (construction-site planning)
R. B. Colton (D)
Geophysical studies:
Pacific Northwest geophysical studies
W. E. Davis (W)
Magnetic studies of Montana laccoliths
R. G. Henderson (W)
Gravity and magnetic studies in western Montana
W. T. Kinoshita (M)
Correlation of aeromagnetic studies and areal geology, Bearpaw Mountains
K. G. Books (W)
Aeromagnetic and gravity studies of the Boulder batholith
W. E. Davis (M)
Gravity studies, Yellowstone area
H. L. Baldwin (D)
Water resources:
Natural flow appraisals (water)
W. A. Blenkarn (s, Helena, Mont.)
Floods from small areas
F. C. Boner (s, Helena, Mont.)
Study of water application and use on a range water spreader in northeast Montana
F. A. Branson (h, D)
Bitterroot Valley, Ravalli County (ground water)
R. G. McMurtery (g, Billings, Mont.)
Lower Bighorn River valley (Hardin Unit) (ground water)
L. J. Hamilton (g, Billings, Mont.)
Northeastern Blaine County (ground water)
E. A. Zimmerman (g, Billings, Mont.)

Montana—Continued
Water resources—Continued
Blue Water Springs area (ground water)
F. A. Swenson (g, Billings, Mont.)
Deer Lodge Valley (ground water)
R. L. Konizeski (g, Billings, Mont.)
Fort Belknap Indian Reservation (ground water)
D. C. Alverson (g. Billings, Mont.)
Southern part of the Judith Basin (ground water)
E. A. Zimmerman (g, Billings, Mont.)
Milk River bottoms, Fort Belknap area (ground water)
W. B. Hopkins (g, Billings, Mont.)
Two Medicine Irrigation project (ground water)
Q. F. Paulson (g, Billings, Mont.)

Nebraska:
Chemical and physical properties of the Pierre shale, Montana, North Dakota, South Dakota, Wyoming, and Nebraska
H. A. Tourtelot (D)
*Lower Republican River
R. D. Miller (D)
*Valley County
R. D. Miller (D)
Subsurface geology of Dakota sandstone, Colorado and Nebraska (oil and gas)
N. W. Bass (D)
Central Nebraska basin (oil and gas)
G. E. Prichard (D)
Omaha-Council Bluffs and vicinity, Nebraska and Iowa (urban geology)
R. D. Miller (D)
Peak discharges from small areas
E. W. Beckman (s, Lincoln, Nebr.)
Bridge-site studies (surface water)
E. W. Beckman (s, Lincoln, Nebr.)
Evapotranspiration study
O. E. Leppanen (h, Phoenix, Ariz.)
Channel patterns and terraces of the Loup Rivers
J. C. Brice (q, Lincoln, Nebr.)
Trap efficiencies of reservoir 1 and 1A, Brownell Creek Subwatershed
J. C. Mundorff (q, Lincoln, Nebr.)
Fillmore County (ground water)
C. F. Keech (g, Lincoln, Nebr.)
Hamilton County (ground water)
C. F. Keech (g, Lincoln, Nebr.)
York County (ground water)
C. F. Keech (g, Lincoln, Nebr.)
Erosion and deposition in Medicine Creek basin
J. C. Brice (q, Lincoln, Nebr.)
Ground water near the Platte River south of Chapman
C. F. Keech (g, Lincoln, Nebr.)
Cedar River valley in the lower Platte River basin (ground water)
J. B. Hyland (g, Lincoln, Nebr.)
Upper Salt Creek drainage basin (ground water)
C. F. Keech (g, Lincoln, Nebr.)

Nevada:
General geology:
Fusuline Foraminifera of Nevada
R. C. Douglass (W)
*Ash Meadows quadrangle, California-Nevada
C. S. Denny (W)

Nevada—Continued
General geology—Continued
*Cortez quadrangle
J. Gilluly (D)
**Esmeralda County
J. P. Albers (M)
*Fallon area
R. B. Morrison (D)
*Frenchie Creek quadrangle
L. J. P. Muffler (D)
*Horse Creek Valley quadrangle
H. Masursky (D)
**Humboldt County
C. R. Willden (M)
Lower Mesozoic stratigraphy and paleontology, Humboldt Range
N. J. Silberling (M)
*Jarbidge area
R. R. Coats (M)
*Kobeh Valley
C. W. Merriam (W)
*Las Vegas-Lake Mead area
C. R. Longwell (M)
**Lincoln County
C. M. Tschanz (M)
**Mineral County
D. C. Ross (M)
*Mt. Lewis and Crescent Valley quadrangles
J. Gilluly (D)
**Northern Nye County
F. J. Kleinhampl (M)
*Owyhee and Mt. City quadrangles, Nevada-Idaho
R. R. Coats (M)
**Pershing County
D. B. Tatlock (M)
*Railroad District, and the Dixie Flats, Pine Valley, and Robinson Mountain quadrangles
J. F. Smith, Jr. (D)
*Schell Creek Range
H. D. Drewes (D)

Mineral resources:
Geochemical halos of mineral deposits, Utah and Nevada
R. L. Erickson (D)
Iron ore deposits
R. G. Reeves (M)
Origin of the borate-bearing marsh deposits of California, Oregon, and Nevada (boron)
W. C. Smith (M)
Stratigraphy and resources of the Phosphoria and Park City formations in Utah and Nevada (phosphate, minor elements)
K. M. Tagg (M)
Western oxidized zinc deposits
A. V. Heyl (W)
*Antler Peak quadrangle (base and precious metals)
R. J. Roberts (M)
*Beatty area (fluorite, bentonite, gold, silver)
H. R. Cornwall (M)
*Regional geologic setting of the Ely district (copper, lead, zinc)
A. L. Brokaw (D)
*Eureka area (zinc, lead, silver, gold)
T. B. Nolan (W)

Nevada—Continued
Mineral resources—Continued
**Eureka County (base and precious metals)
R. J. Roberts (M)
Ione quadrangle (lead, quicksilver, tungsten)
C. J. Vitaliano (Bloomington, Ind.)
*Lyon, Douglas, and Ormsby Counties (copper)
J. G. Moore (M)
*Osgood Mountains quadrangle (tungsten, quicksilver)
P. E. Hotz (M)
*Unionville and Buffalo Mountain quadrangles, Humboldt Range (iron, tungsten, silver, quicksilver)
R. E. Wallace (M)
*Wheeler Peak and Garrison quadrangles, Snake Range (tungsten, beryllium)
D. H. Whitebread (M)
Engineering geology and geophysical studies:
Great Basin geophysical studies
D. R. Mabey (M)
Gravity studies, California-Nevada region
D. J. Stuart (D)
*Geologic and hydrologic environment, Nevada Test Site
F. A. McKeown (D)
*Engineering geology of the Nevada Test Site area
V. R. Wilmarth (D)
Geophysical studies of Nevada Test Site
R. A. Black (D)
Aerial radiological monitoring surveys, Nevada Test Site
J. L. Meuschke (W)
Water resources:
Statewide reconnaissance of ground-water basins
T. E. Eakin (g, Carson City, Nev.)
Northwestern basins (ground water)
W. C. Sinclair (g, Carson City, Nev.)
Fernley-Wadsworth area (ground water)
W. C. Sinclair (g, Carson City, Nev.)
Hydrology of a portion of the Humboldt River Valley
T. W. Robinson (h, M)
Kings River valley (ground water)
C. P. Zones (g, Carson City, Nev.)
Las Vegas basin (ground water)
G. T. Malmberg (g, Carson City, Nev.)
Nevada Test Site (ground water)
S. L. Schoff (g, D)
Pahrump Valley (ground water)
G. T. Malmberg (g, Carson City, Nev.)
Truckee Meadows (ground water)
O. J. Loeltz (g, Carson City, Nev.)

New Hampshire:
Correlation of aeromagnetic studies and areal geology, New Hampshire and Vermont
R. W. Bromery (W)
Seacoast region (ground water)
J. M. Weigle (g, Boston, Mass.)

New Jersey:
*Lower Delaware River basin, New Jersey-Pennsylvania
J. P. Owens (W)
*Middle Delaware River Basin, New Jersey-Pennsylvania
A. A. Drake, Jr. (W)
*Selected iron deposits of the Northeastern States
A. F. Buddington (Princeton, N.J.)
Correlation of aeromagnetic studies and areal geology, New York-New Jersey Highlands (iron)
A. Jesperson (W)

New Jersey—Continued
Chloride in the ground water of New Jersey
P. R. Seaber (g, Trenton, N.J.)
Geochemistry of ground water in the Englishtown formation
P. R. Seaber (g, Trenton, N.J.)
Geologic and hydrologic reconnaissance of potential reactor sites
H. E. Gill (g, Trenton, N.J.)
Flood-frequency analysis
R. H. Tice (s, Trenton, N.J.)
Flood and base-flow gaging
E. G. Miller (s, Trenton, N.J.)
Flood-plain zoning
R. H. Tice (s, Trenton, N.J.)
Flow duration (surface water)
E. G. Miller (s, Trenton, N.J.)
Hydrology and sedimentation of Stony Brook basin
J. R. George (q, Harrisburg, Pa.)
Burlington County (ground water)
F. E. Rush (g, Trenton, N.J.)
Camden County (ground water)
E. Donsky (g, Trenton, N.J.)
Essex County (ground water)
J. Vecchioli (g, Trenton, N.J.)
Gloucester County (ground water)
W. F. Hardt (g, Trenton, N.J.)
Mercer County (ground water)
J. Vecchioli (g, Trenton, N.J.)
Monmouth County (ground water)
L. A. Jablonski (g, Trenton, N.J.)
Morris County (ground water)
H. E. Gill (g, Trenton, N.J.)
Ocean County (ground water)
C. A. Appel (g, Trenton, N.J.)
Salem County (ground water)
J. C. Rosenau (g, Trenton, N.J.)
Passaic Valley (ground water)
J. Vecchioli (g, Trenton, N.J.)
Phillipsburg area (ground water)
J. G. Randolph (g, Trenton, N.J.)
Pine Barrens (ground water)
E. C. Rhodehamel (g, Trenton, N.J.)
Rahway area (ground water)
H. R. Anderson (g, Trenton, N.J.)
Sayreville area (ground water)
C. A. Appel (g, Trenton, N.J.)
Wharton Tract (ground water)
E. C. Rhodehamel (g, Trenton, N.J.)

New Mexico:
General geology:
New Mexico geologic map
C. H. Dane (W)
Stratigraphic significance of the genus *Tempskya* in southwestern New Mexico
C. B. Read (Albuquerque, N. Mex.)
Diatremes, Navajo and Hopi Indian Reservations
E. M. Shoemaker (M)
**Cedar Mountain and Southern Peloncillo Mountains areas
C. S. Bromfield (D)
*Upper Gila River basin, Arizona-New Mexico
R. B. Morrison (D)
Guadelupe Mountains
P. T. Hayes (D)

New Mexico—Continued
General geology—Continued
*Southern Oscura, northern San Andres Mountains
G. O. Bachman (D)
*Philmont Ranch quadrangle
G. D. Robinson (D)
*Petrology of the Valles Mountains
R. L. Smith (W)
Mineral resources:
**Compilation of Colorado Plateau geologic maps (uranium, vanadium)
D. G. Wyant (D)
Colorado Plateau botanical prospecting studies
F. J. Kleinhampl (M)
Uranium-vanadium deposits in sandstone, with emphasis on the Colorado Plateau
R. P. Fischer (D)
Relative concentrations of chemical elements in different rocks and ore deposits of the Colorado Plateau (uranium, vanadium, copper)
A. T. Miesch (D)
Clay studies, Colorado Plateau
L. G. Schultz (D)
Lithologic studies, Colorado Plateau
R. A. Cadigan (D)
Stratigraphic studies, Colorado Plateau (uranium, vanadium)
L. C. Craig (D)
Triassic stratigraphy and lithology of the Colorado Plateau (uranium, copper)
J. H. Stewart (D)
San Rafael group stratigraphy, Colorado Plateau (uranium)
J. C. Wright (D)
Regional relationship of the uranium deposits of northwestern New Mexico
L. S. Hilpert (Salt Lake City, Utah)
Ambrosia Lake district (uranium)
H. C. Granger (D)
*Carrizo Mountains area, Arizona-New Mexico (uranium)
J. D. Strobell (D)
*Grants area (uranium)
R. E. Thaden (Columbia, Ky.)
Mineralogy of uranium-bearing rocks in the Grants area
A. D. Weeks (W)
*Laguna district (uranium)
R. H. Moench (D)
*Tucumcari-Sabinoso area (uranium)
R. L. Griggs (D)
*Silver City region (copper, zinc)
W. R. Jones (D)
Potash and other saline deposits of the Carlsbad area
C. L. Jones (M)
Oil and gas fields
D. C. Duncan (W)
*Franklin Mountains, New Mexico and Texas (petroleum)
R. L. Harbour (D)
*Animas River area, Colorado and New Mexico (coal, oil, and gas)
H. Barnes (D)
*Raton Basin coking coal
G. H. Dixon (M)
*East side San Juan Basin (coal, oil, gas)
C. H. Dane (W)

New Mexico—Continued
Engineering geology and geophysical studies:
*Engineering geology of Gnome Test Site
L. M. Gard (D)
*Nash Draw quadrangle (test-site evaluation)
J. D. Vine (M)
Colorado Plateau regional geophysical studies
H. R. Joesting (W)
Geophysical studies in the Rowe-Mora area
G. E. Andreasen (W)
Water resources:
Hydrologic almanac of New Mexico
W. E. Hale (g, Albuquerque, N. Mex.)
Use of water by municipalities in New Mexico
G. A. Dinwiddie (g, Albuquerque, N. Mex.)
Recharge studies on the High Plains
J. S. Havens (g, Albuquerque, N. Mex.)
Maps showing quality of water by Counties
F. D. Trauger (g, Albuquerque, N. Mex.)
Flood gaging and bridge-site studies
L. A. Wiard (s, Santa Fe, N. Mex.)
Flood-frequency relations
L. A. Wiard (s, Santa Fe, N. Mex.)
The effects of exposure on slope morphology
R. F. Hadley (h, D)
The effects of sediment characteristics on fluvial morphology hydraulics
S. A. Schumm (h, D)
Sediment transport parameters in sand bed streams
J. K. Culbertson (g, Albuquerque, N. Mex.)
Use of tritium in hydrologic studies
C. W. Carlston (g, W)
Acoma and Laguna Indian Reservations (ground water)
J. E. Weir (g, Albuquerque, N. Mex.)
Albuquerque area (ground water)
L. J. Bjorklund (g, Albuquerque, N. Mex.)
Canoncito School facility (ground water)
B. W. Maxwell (g, Albuquerque, N. Mex.)
Carlsbad area (ground water)
L. J. Bjorklund (g, Albuquerque, N. Mex.)
Study of precipitation runoff and sediment yield in Cornfield Wash
D. E. Burkham (h, Albuquerque, N. Mex.)
Test drilling at El Morro National Monument
S. W. West (g, Albuquerque, N. Mex.)
Gallup area (ground water)
S. W. West (g, Albuquerque, N. Mex.)
Ground water studies in conjunction with project Gnome, Eddy County
J. B. Cooper (g, Albuquerque, N. Mex.)
Grant County (ground water)
F. D. Trauger (g, Albuquerque, N. Mex.)
Guadalupe County (ground water)
A. Clebsch (g, Albuquerque, N. Mex.)
Hondo Valley (ground water)
W. A. Mourant (g, Albuquerque, N. Mex.)
Tritium as a tracer in the Lake McMillan underground reservoir
H. O. Reeder (g, Albuquerque, N. Mex.)
Tritium as a tracer in the Ogallala formation in the High Plains, Lea County
H. O. Reeder (g, Albuquerque, N. Mex.)
Northern Lea County (ground water)
H. O. Reeder (g, Albuquerque, N. Mex.)

New Mexico—Continued
Water resources—Continued
Southern Lea County (ground water)
A. Clebsch (g, Albuquerque, N. Mex.)
Southern Luna County (ground water)
G. C. Doty (g, Albuquerque, N. Mex.)
Southeastern McKinley County (ground water)
J. B. Cooper (g, Albuquerque, N. Mex.)
McMillan delta area (ground water)
E. R. Cox (g, Albuquerque, N. Mex.)
Southern Jicarilla Indian Reservation (ground water)
S. W. West (g, Albuquerque, N. Mex.)
Ground-water conditions between Lake McMillan and Carlsbad Springs
E. R. Cox (g(Albuquerque, N. Mex.)
Los Alamos area (ground water)
R. L. Cushman (g, Albuquerque, N. Mex.)
Evaluation of well-field data at Los Alamos
R. L. Cushman (g, Albuquerque, N. Mex.)
Waste contamination studies at Los Alamos (ground water)
J. H. Abrahams (g, Albuquerque, N. Mex.)
Mortandad Canyon (ground water)
J. E. Weir (g, Albuquerque, N. Mex.)
Quay County (ground water)
F. D. Trauger (g, Albuquerque, N. Mex.)
Feasibility of Queen Lake as a disposal area for brine
E. R. Cox (g, Albuquerque, N. Mex.)
Rio Grande Valley near Hot Springs (ground water)
E. R. Cox (g, Albuquerque, N. Mex.)
Ground-water pumpage in the Roswell Basin
R. M. Mower (g, Albuquerque, N. Mex.)
Ground-water recharge in the Roswell Basin
W. S. Motts (g, Albuquerque, N. Mex.)
Roswell Basin water salvage
R. W. Mower (g, Albuquerque, N. Mex.)
Tritium in ground water in the Roswell Basin
J. W. Hood (g, Albuquerque, N. Mex.)
Sandia and Manzano Mountains area (ground water)
F. B. Titus (g, Albuquerque, N. Mex.)
Northern San Juan County (ground water)
F. D. Trauger (g, Albuquerque, N. Mex.)
Particle movement and channel scour and fill of an ephemeral arroya near Santa Fe
L. B. Leopold (w, W)
Three Rivers area (ground water)
J. W. Hood (g, Albuquerque, N. Mex.)
Ground water in structural basins west of Tucumcari
F. D. Trauger (g, Albuquerque, N. Mex.)
Eastern Valencia County (ground water)
F. B. Titus (g, Albuquerque, N. Mex.)
Northern White Sands Integrated Range (ground water)
J. E. Weir (g, Albuquerque, N. Mex.)
Zia, San Ildefonso, and Acoma Indian reservations (ground water)
J. R. Rapp (g, Albuquerque, N. Mex.)

New York:
*Glacial geology of the Elmira-Williamsport area, New York-Pennsylvania
C. S. Denny (W)
*Stratigraphy and structure of Taconic rocks
E-an Zen (W)
*Selected iron deposits of the Northeastern States
A. F. Buddington (Princeton, N.J.)

New York—Continued
Metamorphism and origin of mineral deposits, Gouverneur area
A. E. J. Engel (Pasadena, Calif.)
*Richville quadrangle
H. M. Bannerman (W)
Stratigraphy of the Dunkirk and related beds (oil and gas)
W. de Witt, Jr. (W)
*Stratigraphy of the Dunkirk and related beds, in the Bath and Woodhull quadrangles (oil and gas)
J. F. Pepper (New Philadelphia, Ohio)
*Stratigraphy of the Dunkirk and related beds in the Penn Yan and Keuka Lake quadrangles (oil and gas)
M. J. Bergin (W)
Correlation of aeromagnetic studies and areal geology. Adirondacks area (iron)
J. R. Balsley (W)
Correlation of aeromagnetic studies and areal geology, New York-New Jersey Highlands (iron)
A. Jespersen (W)
Recognition of late glacial substages in New England and New York
J. E. Upson (g, Mineola, N.Y.)
Experimental recharge basin (surface water)
R. M. Sawyer (s, Albany, N.Y.)
Low-flow analyses
B. Dunn (s, Albany, N.Y.)
Small streams (surface water)
O. P. Hunt (s, Albany, N.Y.)
Delaware County (ground water)
J. Soren (g, Albany, N.Y.)
Northeast Nassau County (ground water)
J. Isbister (g, Albany, N.Y.)
Salt-water encroachment in southern Nassau County
N. J. Lusczynski (g, Albany, N.Y.)
Cadmium-chromium contamination in ground water in Nassau County
N. J. Lusczynski (g, Albany, N.Y.)
Orange and Ulster Counties (ground water)
R. D. Duryea (g, Albany, N.Y.)
Queens County (ground water)
N. M. Perlmutter (g, Albany, N.Y.)
Schodack terrace, Rensselaer County (ground water)
J. Joyce (g, Albany, N.Y.)
Flood and low-flow gaging, Rockland County
G. R. Ayer (s, Albany, N.Y.)
Saratoga County (ground water)
R. C. Heath (g, Albany, N.Y.)
Eastern Schenectady County (ground water)
J. D. Winslow (g, Albany, N.Y.)
Mid-island area, western Suffolk County (ground water)
N. M. Perlmutter (g, Albany, N.Y.)
Babylon-Islip area, Suffolk County (ground water)
I. H. Kantrowitz (g, Albany, N.Y.)
Babylon-Islip area (surface water)
E. J. Pluhowski (s, Albany, N.Y.)
Chemical and physical quality of water resources in the Housatonic River basin
E. H. Salvas (q, Albany, N.Y.)
Jamestown area (ground water)
R. A. Wilkens (g, Albany, N.Y.)
Montauk Air Force Station (ground water)
N. M. Perlmutter (g, Albany, N.Y.)

New York—Continued
Niagara Frontier (ground water)
R. H. Johnston (g, Albany, N.Y.)
St. Lawrence River basin (chemical and physical quality of water resources)
A. L. Mattingly (q, Albany, N.Y.)
Syracuse area (ground water)
J. A. Tannenbaum (g, Albany, N.Y.)
West Milton well field
J. D. Winslow (g, Albany, N.Y.)

North Carolina:
*Great Smoky Mountains, Tennessee and North Carolina
J. B. Hadley (D)
*Central Piedmont
H. Bell (W)
*Grandfather Mountain
B. H. Bryant (D)
*Investigations of the Volcanic Slate series
A. A. Stromquist (D)
Massive sulfide deposits of the Ducktown district, Tennessee and adjacent areas (copper, iron, sulfur)
R. M. Hernon (D)
*Swain County copper district
G. H. Espenshade (W)
*Shelby quadrangle (monazite)
W. C. Overstreet (W)
Pegmatites of the Spruce Pine and Franklin-Sylva districts
F. G. Lesure (Knoxville, Tenn.)
*Geologic setting of the Spruce Pine pegmatite district (mica, feldspar)
D. A. Brobst (D)
*Hamme tungsten deposit
J. M. Parker, III (Raleigh, N.C.)
Central and western North Carolina regional aeromagnetic survey
R. W. Johnson, Jr. (Knoxville, Tenn.)
Aeromagnetic studies, Concord-Denton area
R. W. Johnson, Jr. (Knoxville, Tenn.)
Flood gaging
H. G. Hinson (s, Raleigh, N.C.)
Flood-frequency studies
H. G. Hinson (s, Raleigh, N.C.)
Interpretation of data (surface water)
G. C. Goddard (s, Raleigh, N.C.)
Stream sanitation and water supply
G. C. Goddard (s, Raleigh, N.C.)
Salt-water intrusion in coastal streams
J. C. Chemerys (q, Raleigh, N.C.)
Chemical characteristics of public water supplies
K. F. Harris (q, Raleigh, N.C.)
Diagenesis and hydrologic history of the Tertiary limestone of North Carolina
H. E. LeGrand (w, W)
Stratigraphy of the Trent marl and related units
P. M. Brown (g, Raleigh, N.C.)
Ashe and Watauga Counties (quality of water resources)
H. B. Wilder (q, Raleigh, N.C.)
Martin County (ground water)
G. G. Wyrick (g, Raleigh, N.C.)
Blue Ridge Parkway construction sites (ground water)
J. O. Kimrey (g, Raleigh, N.C.)
Cape Hatteras National Park (quality of ground water)
K. F. Harris (q, Raleigh, N.C.)

North Carolina—Continued
Cumberland Gap National Historical Park (ground water)
J. O. Kimrey (g, Raleigh, N.C.)
Dare Beaches Sanitary District (ground water)
J. O. Kimrey (g, Raleigh, N.C.)
Monroe area (ground water)
E. O. Floyd (g, Raleigh, N.C.)
Plymouth area (ground water)
H. Peek (g, Raleigh, N.C.)
Southport area (ground water)
P. M. Brown (g, Raleigh, N.C.)

North Dakota:
Chemical and physical properties of the Pierre shale, Montana, North Dakota, South Dakota, Wyoming, and Nebraska
H. A. Tourtelot (D)
Williston Basin oil and gas studies, Wyoming, Montana, North Dakota, and South Dakota
C. A. Sandberg (D)
Geology of the Williston Basin with reference to the disposal of high-level radioactive wastes
C. A. Sandberg (D)
Peak discharges from small areas
O. A. Crosby (s, Bismarck, N. Dak.)
Hydrology of prairie potholes
J. B. Shejeflo (h, D)
Glacial valleys in Divide, Williams, and McKenzie Counties (ground water)
E. Bradley (g, Grand Forks, N. Dak.)
Kidder County (ground water)
E. Bradley (g, Grand Forks, N. Dak.)
Stutsman County (ground water)
C. J. Huxel (g, Grand Forks, N. Dak.)
Traill County (ground water)
H. M. Jensen (g, Grand Forks, N. Dak.)
Bowbells area (ground water)
H. M. Jensen (g, Grand Forks, N. Dak.)
Cheyenne and Standing Rock Indian Reservations (ground water)
J. E. Powell (g, Huron, S. Dak.)
Devils Lake area (ground water)
P. D. Akin (g, Grand Forks, N. Dak.)
Chemical quality of surface waters, Devils Lake area
P. G. Rosene (q, Lincoln, Nebr.)
Chemical quality of surface waters and sedimentation in the Grand River drainage basin
P. R. Jordan (q, Lincoln, Nebr.)
Chemical quality of surface waters and sedimentation in the Heart River drainage basin
M. A. Maderak (q, Lincoln, Nebr.)
Heimdal valley; Wells, Eddy, and Foster Counties (ground water)
E. Bradley (g, Grand Forks, N. Dak.)
Lakota area (ground water)
E. Bradley (g, Grand Forks, N. Dak.)
Special streamflow measurements of the Souris River at Minot
E. Bradley (g, Grand Forks, N. Dak.)
Strasburg-Linton area (ground water)
P. Randich (g, Grand Forks, N. Dak.)
Tioga area (ground water)
C. J. Huxel (g, Grand Forks, N. Dak.)

Ohio:
*Geology and coal resources of Belmont County
H. L. Berryhill, Jr. (D)
Seismic survey for buried valleys in Ohio
R. M. Hazelwood (D)
Floods of January and February 1959
W. P. Cross (s, Columbus, Ohio)
Low flow and storage requirements
W. P. Cross (s, Columbus, Ohio)
Glacial mapping in Ohio
G. W. White (g, Columbus, Ohio)
Mapping of buried valleys
S. E. Norris (g, Columbus, Ohio)
Northeastern Ohio (ground water)
J. L. Rau (g, Columbus, Ohio)
Fairfield County (ground water)
G. D. Dove (g, Columbus, Ohio)
Geauga County (ground water)
J. Baker (g, Columbus, Ohio)
Portage County (ground water)
J. D. Winslow (g, Columbus, Ohio)
Canton area (ground water)
J. D. Winslow (g, Columbus, Ohio)
Dayton area (ground water)
S. E. Norris (g, Columbus, Ohio)
Hamilton-Middletown area
S. E. Norris (g, Columbus, Ohio)
Venice area
A. M. Spieker (g, Columbus, Ohio)

Oklahoma:
Tri-State lead-zinc district, Oklahoma, Missouri, Kansas
E. T. McKnight (W)
Anadarko Basin, Oklahoma and Texas (oil and gas)
W. L. Adkison (Lawrence, Kans.)
McAlester Basin (oil and gas)
S. E. Frezon (D)
*Ft. Smith district. Arkansas and Oklahoma (coal and gas)
T. A. Hendricks (D)
Trace elements in rocks of Pennsylvanian age, Oklahoma, Kansas, Missouri (uranium, phosphate)
W. Danilchik (Quetta, Pakistan)
Geology of the Anadarko Basin with reference to disposal of high-level radioactive wastes
M. MacLachlan (D)
Thickness of the fresh ground-water zone in Oklahoma
D. L. Hart (g, Norman, Okla.)
Water-quality conservation in the Arkansas and Red River basins
P. E. Ward (g, Norman, Okla.)
Saline surface-water resources of Oklahoma
R. P. Orth (q, Oklahoma City, Okla.)
Land-use evaluation
F. W. Kennon (h, Oklahoma City, Okla.)
Beaver County (ground water)
I. W. Marine (g, Norman, Okla.)
Garber sandstone in Cleveland and Wellington Counties (ground water)
A. R. Leonard (g, Norman, Okla.)
Woodward County (ground water)
B. L. Stacy (g, Norman, Okla.)
Ground water in the Arbuckle limestone in the northeastern Arbuckle Mountains
I. W. Marine (g, Norman, Okla.)

Oklahoma—Continued
Arkansas and Verdigris River valleys (ground water)
H. H. Tanaka (g, Norman, Okla.)
Upper Arkansas River basin (quality of surface water)
R. P. Orth (q, Oklahoma City, Okla.)
Beaver Creek basin (quality of surface water)
R. P. Orth (q, Oklahoma City, Okla.)
Clinton-Sherman Air Force Base (ground water)
A. R. Leonard (g, Norman, Okla.)
Little River basin (quality of surface water)
G. Bednar (q, Oklahoma City, Okla.)
Otter and Elk Creek basins (ground water)
J. R. Hollowell (g, Norman, Okla.)
Ground water in the Rush Springs sandstone
H. H. Tanaka (g, Norman, Okla.)
Washita River basin (quality of surface water)
J. J. Murphy (q, Oklahoma City, Okla.)

Oregon:
Oregon state geologic map
G. W. Walker (M)
Cenozoic mollusks
E. J. Moore (M)
**Canyon City 2° quadrangle
T. P. Thayer (W)
*Monument quadrangle
R. E. Wilcox (D)
*Newport Embayment
P. D. Snavely, Jr. (M)
Origin of the borate-bearing marsh deposits of California, Oregon, and Nevada (boron)
W. C. Smith (M)
*John Day area (chromite)
T. P. Thayer (W)
*Quartzburg district (cobalt)
J. S. Vhay (Spokane, Wash.)
Lateritic nickel deposits of the Klamath Mountains, Oregon-California
P. E. Hotz (M)
*Anlauf and Drain quadrangles (oil and gas)
L. Hoover (W)
*Ochoco Reservation, Lookout Mountain, Eagle Rock, and Post quadrangles (quicksilver)
A. C. Waters (Baltimore, Md.)
Pacific Northwest geophysical studies
W. E. Davis (W)
Aeromagnetic and gravity studies in west-central Oregon
R. W. Bromery (W)
Aerial radiological monitoring surveys, Hanford area
R. G. Schmidt (W)
*Portland industrial area, Oregon and Washington (urban geology)
D. E. Trimble (D)
Sediment production of forested watersheds
R. C. Williams (q, Portland, Oreg.)
Appraisal of water quality and water-quality problems of selected streams
R. J. Madison (q, Portland, Oreg.)
Lower Columbia River Basin (quality of surface water)
J. F. Santos (q, Portland, Oreg.)
Columbia River basalt hydrology
R. C. Newcomb (g, Portland, Oreg.)
Artificial recharge of basalt aquifers at the Dalles
B. L. Foxworthy (g, Portland, Oreg.)

Oregon—Continued
- Eola and Amity Hills (ground water)
  - D. Price (g, Portland, Oreg.)
- Florence area (ground water)
  - E. R. Hampton (g, Portland, Oreg.)
- Fort Rock basin (ground water)
  - E. R. Hampton (g, Portland, Oreg.)
- French Prairie (ground water)
  - D. Price (g, Portland, Oreg.)
- East Portland area (ground water)
  - B. L. Foxworthy (g, Portland, Oreg.)
- West Portland area (ground water)
  - S. G. Brown (g, Portland, Oreg.)
- Raft River basin water records
  - M. J. Mundorff (g, Portland, Oreg.)
- Tumalo District, Deschutes County (ground water)
  - B. L. Foxworthy (g, Portland, Oreg.)
- Northern Willamette valley east of Pudding River (ground water)
  - E. R. Hampton (g, Portland, Oreg.)

Pennsylvania:
- *Bituminous coal resources
  - E. D. Patterson (W)
- Correlation of aeromagnetic studies and areal geology, Pennsylvania Triassic area
  - R. W. Bromery (W)
- *Lower Delaware River Basin, New Jersey-Pennsylvania
  - J. P. Owens (W)
- *Middle Delaware River Basin, New Jersey-Pennsylvania
  - A. A. Drake, Jr. (W)
- *Glacial geology of the Elmira-Williamsport area, New York-Pennsylvania
  - C. S. Denny (W)
- *Investigations of the Lower Cambrian of the Philadelphia district
  - J. H. Wallace (W)
- *Southern anthracite field
  - G. H. Wood, Jr. (W)
- *Western middle anthracite field
  - H. H. Arndt (W)
- *Flood control, Anthracite region
  - T. M. Kehn (Mt. Carmel, Pa.)
- *Geology in the vicinity of anthracite mine drainage projects
  - T. M. Kehn (Mt. Carmel, Pa.)
- Selected studies of uranium deposits
  - H. Klemic (W)
- *Lehighton quadrangle (uranium)
  - H. Klemic (W)
- Washington County (coal)
  - H. Berryhill, Jr. (D)
- Flood-frequency analysis
  - W. F. Busch (s, Harrisburg, Pa.)
- Low-flow frequency analysis
  - W. F. Busch (s, Harrisburg, Pa.)
- Mining hydrology
  - W. T. Stuart (g, W)
- Allegheny River basin (chemical quality of surface water)
  - D. McCartney (q, Philadelphia. Pa.)
- Chemical characteristics of Delaware River water
  - D. McCartney (q, Philadelphia, Pa.)

Pennsylvania—Continued
- Salinity conditions of Lower Delaware River basin
  - D. McCartney (q, Philadelphia, Pa.)
- Lehigh River basin (quality of surface water)
  - W. B. Keighton (q, Philadelphia, Pa.)
- Time of travel of Ohio River water
  - R. E. Steacy (s, Harrisburg, Pa.)
- Potomac River basin
  - P. M. Johnston (g, W)
- Raritan River basin (quality of surface water)
  - J. R. George (q, Harrisburg, Pa.)
- Hydrology and sedimentation of Bixler Run, Corey Creek, and Elk Run basins
  - J. R. George (q, Harrisburg, Pa.)
- Brunswick formation (ground water)
  - S. M. Longwill (g, Harrisburg, Pa.)
- Flood-inundation map, Harrisburg
  - L. A. Heckmiller (s, Harrisburg, Pa.)
- Hydrology of limestones in the Lebanon Valley
  - H. Meisler (g, Harrisburg, Pa.)
- Mercer and Neshannock quadrangles (ground water)
  - C. W. Poth (g, Harrisburg, Pa.)
- New Oxford formation (ground water)
  - P. R. Wood (g, Harrisburg, Pa.)
- Red Clay Valley (ground water)
  - D. H. Boggess (g, Newark, Del.)
- Shenango and Stoneboro quadrangles
  - L. D. Carswell (g, Harrisburg, Pa.)

Rhode Island:
- *Ashaway quadrangle, Rhode Island-Connecticut; bedrock geologic mapping
  - T. G. Feininger (Boston, Mass.)
- *Carolina, Quonochontaug, Narragansett Pier, and Wickford quadrangles, Rhode Island; and Ashaway and Watch Hill quadrangles, Connecticut-Rhode Island; surficial geologic mapping
  - J. P. Schafer (Boston, Mass.)
- *Chepachet, Crompton, and Tiverton quadrangles; bedrock geologic mapping
  - A. W. Quinn (Providence, R.I.)
- *Coventry Center, Kingston, and Newport quadrangles, Rhode Island; and Watch Hill quadrangle, Connecticut-Rhode Island; bedrock geologic mapping
  - G. E. Moore, Jr. (Columbus, Ohio)
- *Hope Valley quadrangle; surficial geologic mapping
  - T. G. Feininger (Boston, Mass.)
- *Kingston quadrangle; surficial geologic mapping
  - C. A. Kaye (Boston, Mass.)
- *North Scituate quadrangle; surficial geologic mapping
  - C. S. Robinson (D)
- *Thompson quadrangle, Connecticut-Rhode Island
  - P. M. Hanshaw (Boston, Mass.)
- *Wickford quadrangle; bedrock geologic mapping
  - R. B. Williams (Providence, R.I.)
- Oneco quadrangle (ground water)
  - K. E. Johnson (g, Providence, R.I.)
- Upper Pawcatuck basin (ground water)
  - W. B. Allen (g, Providence, R.I.)
- Voluntown quadrangle (ground water)
  - K. E. Johnson (g, Providence, R.I.)
- Watch Hill quadrangle (ground water)
  - K. E. Johnson (g, Providence, R.I.)

South Carolina:

Crystalline rocks of South Carolina
W. C. Overstreet (W)

Aerial radiological monitoring surveys, Savannah River Plant, Georgia and South Carolina
R. G. Schmidt (W)

Flood gaging
W. W. Evett (s, Columbia, S.C.)

Drainage-area determinations
W. M. Bloxham (s, Columbia, S.C.)

Flood-frequency analysis
F. H. Wagener (s, Columbia, S.C.)

Artesian water in Tertiary limestones in Florida, southern Georgia, and adjacent parts of Alabama and South Carolina
V. T. Stringfield (w, W)

Stratigraphy of the Trent marl and related units
P. M. Brown (g, Raleigh, N.C.)

Northeastern coastal plain (ground water)
G. E. Siple (g, Columbia, S.C.)

Coastal plain (ground water)
G. E. Siple (g, Columbia, S.C.)

Flood-plain aquifers
G. E. Siple (g, Columbia, S.C.)

Salt-water intrusion in Lower Edisto River basin
G. A. Billingsley (q, Raleigh, N.C.)

Santee River basin flood study
A. E. Johnson (s, Columbia, S.C.)

Savannah River AEC plant (ground water)
N. C. Koch (g, Columbia, S.C.)

South Dakota:

Chemical and physical properties of the Pierre shale, Montana, North Dakota, South Dakota, Wyoming, and Nebraska
H. A. Tourtelot (D)

Williston Basin oil and gas studies, Wyoming, Montana, North Dakota, and South Dakota
C. A. Sandberg (D)

Geology of the Williston Basin with reference to the disposal of high-level radioactive wastes
C. A. Sandberg (D)

*Southern Black Hills (pegmatite minerals)
J. J. Norton (W)

*Pegmatites of the Custer district
J. A. Redden (Blacksburg, Va.)

*Structure and metamorphism, Hill City quadrangle (pegmatite minerals)
J. C. Ratté (D)

*Southern Black Hills (uranium)
G. B. Gott (D)

*Harding County, South Dakota, and adjacent areas (uraniferous lignite)
G. N. Pipiringos (D)

Regional gravity studies in uranium geology, Black Hills area
R. M. Hazlewood (D)

Landslide studies in the Fort Randall Reservoir area
H. D. Varnes (D)

Studies of artesian wells and selected shallow aquifers
C. F. Dyer (g, Huron, S. Dak.)

Peak discharges from small areas
R. E. West (s, Pierre, S. Dak.)

South Dakota—Continued

Hydrology of prairie potholes
J. B. Shjeflo (h, D)

Hydrology of glacial drift in selected drainage basins in eastern South Dakota
M. J. Ellis (g, Huron, S. Dak.)

Dakota sandstone (ground water)
C. F. Dyer (g, Huron, S. Dak.)

Minor constituents in the Belle Fourche River
L. R. Petri (q, Lincoln, Nebr.)

Cheyenne and Standing Rock Indian Reservations (ground water)
J. E. Powell (g, Huron, S. Dak.)

Flandreau area (ground water)
J. E. Powell (g, Huron, S. Dak.)

Chemical quality of surface waters and sedimentation in the Grand River drainage basin
P. R. Jordan (q, Lincoln, Nebr.)

Sanborn County (ground water)
L. W. Howells (g, Huron, S. Dak.)

Shadehill Reservoir area (ground water)
J. E. Powell (g, Huron, S. Dak.)

Tennessee:

*Geology of the southern Appalachian folded belt, Kentucky, Tennessee, and Virginia
L. D. Harris (W)

*Great Smoky Mountains, Tennessee and North Carolina
J. B. Hadley (D)

Ivydell, Pioneer, Jellico West, and Ketchen quadrangles (coal)
K. J. Englund (W)

Massive sulfide deposits of the Ducktown district, Tennessee and adjacent areas (copper, iron, sulfur)
R. M. Hernon (D)

Clinton iron ores of the southern Appalachians
R. P. Sheldon (D)

*East Tennessee zinc studies
A. L. Brokaw (D)

Origin and depositional control of some Tennessee and Virginia zinc deposits
H. Wedow, Jr. (Knoxville, Tenn.)

Central and western North Carolina regional aeromagnetic survey
R. W. Johnson, Jr. (Knoxville, Tenn.)

Aeromagnetic studies, Middlesboro-Morristown area, Tennessee-Kentucky-Virginia
R. W. Johnson, Jr. (Knoxville, Tenn.)

Aeromagnetic study of peridotite, Maynardville
R. W. Johnson, Jr. (Knoxville, Tenn.)

Aerial radiological monitoring surveys, Oak Ridge National Laboratory
R. G. Bates (W)

*Knoxville and vicinity (urban geology)
J. M. Cattermole (D)

Low-flow studies
J. S. Cragwall, Jr. (s, Chattanooga, Tenn.)

Flood-frequency analysis
W. J. Randolph (s, Chattanooga, Tenn.)

Bridge-site studies (surface water)
I. J. Hickenlooper (s, Chattanooga, Tenn.)

Large springs of eastern Tennessee
P. C. Sun (g, Nashville, Tenn.)

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Tennessee—Continued
Western Tennessee (ground water)
G. K. Moore (g, Nashville, Tenn.)
Flood profiles, Chattanooga Creek
A. M. F. Johnson (s, Chattanooga, Tenn.)
Dover area (ground water)
M. V. Marcher (g, Nashville, Tenn.)
Highland Rim Plateau (ground water)
M. V. Marcher (g, Nashville, Tenn.)
Madison County (ground water)
D. J. Nyman (g, Nashville, Tenn.)
Memphis area (ground water)
P. C. Sun (g, Nashville, Tenn.)
Texas:
*Del Rio area
V. L. Freeman (D)
*Sierra Blanca area
J. F. Smith, Jr. (D)
*Sierra Diablo region
P. B. King (M)
Sierra Madera
E. M. Shoemaker (M)
Anadarko Basin, Oklahoma and Texas (oil and gas)
W. L. Adkison (Lawrence, Kans.)
*Franklin Mountains, New Mexico and Texas (petroleum)
R. L. Harbour (D)
*Wayland quadrangle (oil and gas investigations)
D. A. Myers (D)
Mineralogy of uranium-bearing rocks in Karnes and Duval Counties
A. D. Weeks (W)
*Texas coastal plain geophysical and geological studies
D. H. Eargle (Austin, Tex.)
Aerial radiological monitoring surveys, Fort Worth
J. A. Pitkin (W)
Use of tritium in hydrologic studies
C. W. Carlston (g, W)
Drainage-area determinations, Sabine, Neches, San Jacinto, and Trinity River basins
P. H. Holland (s, Austin, Tex.)
Hydrologic investigations, small watersheds, Trinity, Brazos, Colorado, and San Antonio River basins
W. H. Goines (s, Austin, Tex.)
Thermal surveys, Lake Colorado City
G. H. Hughes (s, Austin, Tex.)
Field testing of evaporation suppression on small reservoirs
G. E. Koberg (h, D)
Hydrologic effect of small reservoirs, Honey Creek
F. W. Kennon (h, Oklahoma City, Okla.)
Evaporation suppression studies (Throckmorton)
G. E. Koberg (h, D)
Trap-efficiency of reservoir on Escondido Creek
C. T. Welborn (q, Austin, Tex.)
Carson and adjoining counties (ground water)
A. T. Long (g, Austin, Tex.)
Haskell and Knox Counties (ground water)
W. Ogilbee (g, Austin, Tex.)
Northern Jim Wells County and adjacent areas (ground water)
C. C. Mason (g, Austin, Tex.)
Hydrologic investigations, urban watershed, Austin
A. E. Hulme (s, Austin, Tex.)
El Paso area (ground water)
M. E. Davis (g, Austin, Tex.)

Texas—Continued
Galveston area (ground water)
R. B. Anders (g, Austin, Tex.)
Houston district (ground water)
R. B. Anders (g, Austin, Tex.)
San Antonio area (ground water)
S. Garza (g, Austin, Tex.)
Brazos River saline investigations
J. O. Joerns (s, Austin, Tex.)
Sources of salinity in the Upper Brazos River basin
R. C. Baker (g, Austin, Tex.)
Sources of salinity in the Upper Brazos River basin
L. S. Hughes (q, Austin, Tex.)
High Plains north of the Canadian River (ground water)
W. H. Alexander (g, Austin, Tex.)
Upper and lower Rio Grande basins, Brazos, Red, and Gulf Coast basins (ground water)
L. A. Wood (g, Austin, Tex.)
Middle Rio Grande basin, Colorado, Trinity, and Sabine River basins (ground water)
R. C. Peckham (g, Austin, Tex.)
Low-flow investigations, Sabine River
P. H. Holland (s, Austin, Tex.)
Sedimentation conditions in Upper Trinity River basin
C. T. Welborn (q, Austin, Tex.)
Utah:
General geology:
Upper Cretaceous stratigraphy, northwestern Colorado and northeastern Utah
A. D. Zapp (D)
Tuffs of the Green River formation
R. L. Griggs (D)
*Northern Bonneville Basin
J. S. Williams (Provo, Utah)
*Cedar City area
P. Averitt (D)
*Confusion Range
R. K. Hose (M)
*Little Cottonwood area
G. M. Richmond (D)
*Strawberry Valley and Wasatch Mountains
A. A. Baker (W)
*South half, Utah Valley
H. J. Bissell (Provo, Utah)
Mineral resources:
Geochemical halos of mineral deposits, Utah and Nevada
R. L. Erickson (D)
*Marysvale district (alunite)
R. L. Parker (D)
*Cedar Mountain quadrangle, Iron County (coal)
P. Averitt (D)
*Southern Kolob Terrace coal field
W. B. Cashion (D)
*Regional geologic setting of the Bingham Canyon district (copper)
R. J. Roberts (M)
Thomas and Dugway Ranges (fluorspar, beryllium)
M. H. Staatz (D)
*Fuels potential of the Navajo Reservation, Arizona and Utah
R. B. O'Sullivan (D)
*Alta quadrangle (lead, silver, phosphate rock)
M. D. Crittenden, Jr. (M)

Utah—Continued
Mineral resources—Continued
*East Tintic lead-zinc district, including extensive geochemical studies
H. T. Morris (M)
*San Francisco Mountains (base metals, tungsten)
D. M. Lemmon (M)
*Uinta Basin oil shale
W. B. Cashion (D)
Stratigraphy and resources of the Phosphoria and Park City formations in Utah and Nevada (phosphate, minor elements)
K. M. Tagg (M)
*Wheeler Peak and Garrison quadrangles, Snake Range, Nevada and Utah (tungsten, beryllium)
D. H. Whitebread (M)
**Compilation of Colorado Plateau geologic maps (uranium, vanadium)
D. G. Wyant (D)
Uranium-vanadium deposits in sandstone, with emphasis on the Colorado Plateau
R. P. Fischer (D)
Relative concentrations of chemical elements in different rocks and ore deposits of the Colorado Plateau (uranium, vanadium, copper)
A. T. Miesch (D)
Colorado Plateau botanical prospecting studies
F. J. Kleinhampl (M)
Clay studies, Colorado Plateau
L. G. Schultz (D)
Lithologic studies, Colorado Plateau
R. A. Cadigan (D)
Stratigraphic studies, Colorado Plateau (uranium, vanadium)
L. C. Craig (D)
Triassic stratigraphy and lithology of the Colorado Plateau (uranium, copper)
J. H. Stewart (D)
San Rafael group stratigraphy, Colorado Plateau (uranium)
J. C. Wright (D)
*Abajo Mountains (uranium, vanadium)
I. J. Witkind (D)
*Circle Cliffs area (uranium)
E. S. Davidson (Tucson, Ariz.)
*Deer Flat area, White Canyon district (uranium, copper)
T. L. Finnell (D)
*Elk Ridge area (uranium)
R. Q. Lewis (D)
*La Sal area, Utah-Colorado (uranium, vanadium)
W. D. Carter (Santiago, Chile)
*Lisbon Valley area, Utah-Colorado (uranium, vanadium, copper)
G. W. Weir (M)
*Interriver area, east-central Utah (uranium)
E. N. Hinrichs (D)
*Orange Cliffs area (uranium)
F. A. McKeown (D)
*Sage Plain area (uranium and vanadium)
L. C. Huff (D)
Uranium ore controls of the San Rafael Swell
C. C. Hawley (D)

Utah—Continued
Mineral resources—Continued
*White Canyon area (uranium, copper)
R. E. Thaden (D)
Western oxidized zinc deposits
A. V. Heyl (W)
Engineering geology and geophysical studies:
*Geologic factors related to coal mine bumps
F. W. Osterwald (D)
*Upper Green River Valley (construction-site planning)
W. R. Hansen (D)
*Surficial geology of the Oak City area (construction-site planning)
D. J. Varnes (D)
Colorado Plateau regional geophysical studies
H. R. Joesting (W)
Great Basin geophysical studies
D. R. Mabey (M)
Water resources:
Flood gaging
V. K. Berwick (s, Salt Lake City, Utah)
Pumping districts of southern Utah (ground water)
G. W. Sandberg (g, Salt Lake City, Utah)
Dissolved mineral contributions to Great Salt Lake
A. M. Diaz (q, Salt Lake City, Utah)
Study of the mechanics of hillslope erosion
S. A. Schumm (h, D)
Evaluation of sediment barrier on Sheep Creek, Paria River Basin, near Tropic
G. C. Lusby (h, D)
Dinosaur National Monument (ground water)
R. E. Smith (g, Salt Lake City, Utah)
Lodore Canyon, Deerlodge Park, and Dinosaur National Monument (ground water)
R. E. Smith (g, Salt Lake City, Utah)
East Shore area (ground water)
R. E. Smith (g, Salt Lake City, Utah)
Jordan Valley (ground water)
I. W. Marine (g, Salt Lake City, Utah)
Pavant Valley (ground water)
R. W. Mower (g, Salt Lake City, Utah)
Central Sevier Valley (ground water)
R. A. Young (g, Salt Lake City, Utah)
Upper Sevier Valley (ground water)
R. A. Young (g, Salt Lake City, Utah)
Tooele Valley (ground water)
H. D. Goode (g, Salt Lake City, Utah)
Uinta Basin (ground water)
H. D. Goode (g, Salt Lake City, Utah)
Northern Utah Valley (ground water)
S. Subitzky (g, Salt Lake City, Utah)
Wasatch front (ground water)
R. E. Smith (g, Salt Lake City, Utah)
Weber Basin (ground water)
J. H. Feth (g, Salt Lake City, Utah)
Vermont:
*Talc and asbestos deposits of north-central Vermont
W. M. Cady (D)
Correlation of aeromagnetic studies and areal geology, New Hampshire and Vermont
R. W. Bromery (W)

Virginia:
*Geology of the southern Appalachian folded belt, Kentucky, Tennessee, and Virginia
L. D. Harris (W)
*Potomac Basin studies, Maryland, Virginia, and West Virginia
J. T. Hack (W)
*Herndon quadrangle (construction-site planning)
R. E. Eggleton (D)
*Petrology of the Manassas quadrangle
C. Milton (W)
Origin and depositional control of some Tennessee and Virginia zinc deposits
H. Wedow, Jr. (Knoxville, Tenn.)
Massive sulfide deposits of the Ducktown district, Tennessee and adjacent areas (copper, iron, sulfur)
R. M. Hernon (D)
Aerial radiological monitoring surveys, Belvoir area, Virginia and Maryland
S. K. Neuschel (W)
Aeromagnetic studies, Middlesboro-Morristown area, Tennessee-Kentucky-Virginia
R. W. Johnson, Jr. (Knoxville, Tenn.)
Hydrologic and hydraulic studies
C. W. Lingham (s, Charlottesville, Va.)
Flood investigations
C. W. Lingham (s, Charlottesville, Va.)
Flood-plain zoning
D. G. Anderson (s, Charlottesville, Va.)
Flood hydrology, Fairfax County and Alexandria City
D. G. Anderson (s, Charlottesville, Va.)
Effect of urbanization of peak discharge
R. W. Carter (s, W)
Potomac River basin
P. M. Johnston (g, W)

Washington:
*Bald Knob quadrangle
M. H. Staatz (D)
*Glacier Peak quadrangle
D. F. Crowder (M)
*Grays Harbor basin
H. D. Gower (M)
*Northern Olympic Peninsula
R. D. Brown, Jr. (M)
Osceola mudflow studies
D. R. Crandell (D)
*Republic quadrangle
J. A. Calkins (D)
**Geologic mapping of the Spokane-Wallace region, Washington-Idaho
A. B. Griggs (M)
*Greenacres quadrangle, Washington-Idaho (high-alumina clays)
P. L. Weis (Spokane, Wash.)
Coal resources
H. D. Gower (M)
*Maple Valley, Hobart and Cumberland quadrangles, King County (coal)
J. D. Vine (M)
*Holden and Lucerne quadrangles, Northern Cascade Mountains (copper)
F. W. Cater (D)

Washington—Continued
*Metaline lead-zinc district
M. G. Dings (D)
*Stevens County lead-zinc district
R. G. Yates (M)
*Chewelah area (magnesite)
I. Campbell (San Francisco, Calif.)
*Hunters quadrangle (magnesite, tungsten, base metals, barite)
A. B. Campbell (D)
*Mt. Spokane quadrangle (uranium)
A. E. Weissenborn (Spokane, Wash.)
*Turtle Lake quadrangle (uranium)
G. E. Becraft (D)
Pacific Northwest geophysical studies
W. E. Davis (W)
Gravity survey of western Washington
D. J. Stuart (W)
Aerial radiological monitoring surveys, Hanford
R. G. Schmidt (W)
*Portland industrial area, Oregon and Washington (urban geology)
D. E. Trimble (D)
*Puget Sound basin (urban geology and construction-site planning)
D. R. Mullineaux (D)
Engineering geologic studies of Seattle
D. R. Mullineaux (D)
Drainage area compilation
D. Richardson (s, Tacoma, Wash.)
Effect of changes in forest cover on streamflow
F. M. Veatch (s, Tacoma, Wash.)
Glacialogical research
M. F. Meier (h, Tacoma, Wash.)
Geomorphology of glacier streams
R. K. Fahnestock (h, Fort Collins, Colo.)
Relationship of ground-water storage and streamflow, Columbia River basin
A. A. Garrett (g, Tacoma, Wash.)
Columbia River basalt hydrology
R. C. Newcomb (g, Portland, Oreg.)
Columbia Basin Irrigation Project (ground water)
J. W. Bingham (g, Tacoma, Wash.)
Lower Columbia River basin (quality of surface water).
J. F. Santos (q, Portland, Oreg.)
Grant, Adams, and Franklin Counties (ground water)
M. J. Grolier (g, Tacoma, Wash.)
Southwest King County (ground water)
K. L. Walters (g, Tacoma, Wash.)
Central Pierce County (ground water)
K. L. Walters (g, Tacoma, Wash.)
Thurston County (ground water)
E. F. Wallace (g, Tacoma, Wash.)
Whitman County (ground water)
K. L. Walters (g, Tacoma, Wash.)
Whitman National Monument (ground water)
J. W. Bingham (g, Tacoma, Wash.)
Hydrology of Lower Flett Creek basin
F. M. Veatch (s, Tacoma, Wash.)
Kitsap Peninsula (surface water)
E. G. Bailey (s, Tacoma, Wash.)
Nooksack River basin (surface water)
E. G. Bailey (s, Tacoma, Wash.)

West Virginia:

*Potomac Basin studies, Maryland, Virginia, and West Virginia
J. T. Hack (W)

Aerial radiological monitoring surveys, Belvoir area, Virginia and Maryland
S. K. Neuschel (W)

General hydrology
W. L. Doll (s, Charleston, W. Va.)

Potomac River basin (ground water)
P. M. Johnson (g, W)

Lower Kanawha River valley (ground water)
B. M. Wilmoth (g. Morgantown, W. Va.)

Ohio County (ground water)
G. Meyer (g, Morgantown, W. Va.)

Teays Valley (ground water)
E. C. Rhodehamel (g, Morgantown, W. Va.)

Wisconsin:

*Florence County (iron)
C. E. Dutton (Madison, Wis.)

*Wisconsin zinc-lead mining district
J. W. Whitlow (D)

*Stratigraphy of the lead-zinc district near Dubuque
J. W. Whitlow (W)

Geophysical studies in the Lake Superior region
G. D. Bath (M)

Correlation of aeromagnetic studies and areal geology, Florence County
R. W. Johnson, Jr. (Knoxville, Tenn.)

Correlation of aeromagnetic studies and areal geology near Wausau
J. W. Allingham (W)

Regional flood frequency
D. W. Ericson (s, Madison, Wis.)

Exploration of valley fills by seismic refraction
G. H. Dury (w, W)

Northwestern Wisconsin (ground water)
R. W. Ryling (g, Madison, Wis.)

Dane County (ground water)
D. R. Cline (g, Madison, Wis.)

Portage County (ground water)
C. L. R. Holt (g, Madison, Wis.)

Rock County (ground water)
E. F. LeRoux (g, Madison, Wis.)

Waupaca County (ground water)
C. F. Berkstresser (g, Madison, Wis.)

Waushara County (ground water)
W. K. Summers (g, Madison, Wis.)

Evolution of Black Earth Creek and Mounds Creek
G. H. Dury (w, W)

Green Bay area (ground water)
D. B. Knowles (g, Madison, Wis.)

Milwaukee area (ground water)
R. W. Ryling (g, Madison, Wis.)

Little Plover River basin (ground water)
D. B. Knowles (g, Madison, Wis.)

Wyoming:

General geology and engineering geology:

Pennsylvanian and Permian stratigraphy, Rocky Mountain Front Range, Colorado and Wyoming
E. K. Maughan (D)

Investigation of Jurassic stratigraphy, south-central Wyoming and northwestern Colorado
G. N. Pipiringos (D)

Wyoming—Continued

General geology and engineering geology—Continued

Chemical and physical properties of the Pierre shale, Montana, North Dakota, South Dakota, Wyoming, and Nebraska.
H. A. Tourtelot (D)

Stratigraphy and paleontology of the Pierre shale, Front Range area, Colorado and Wyoming
W. A. Cobban and G. R. Scott (D)

Geology and paleolimnology of the Green River formation
W. H. Bradley (W)

Mineralogy and geochemistry of the Green River formation
C. Milton (W)

Tuffs of the Green River formation
R. L. Griggs (D)

Geology of the Williston Basin with reference to the disposal of high-level radioactive wastes
C. A. Sandberg (D)

*Big Piney area
S. S. Oriel (D)

*Clark Fork area
W. G. Pierce (M)

*Cokeville quadrangle
W. W. Rubey (W)

*Fort Hill quadrangle
S. S. Oriel (D)

Fossil Basin, southwest Wyoming
J. I. Tracey, Jr. (W)

*Geology of Grand Teton National Park
J. D. Love (Laramie, Wyo.)

*Upper Green River valley (construction-site planning)
W. R. Hansen (D)

Geology of the Powder River basin with reference to the disposal of high-level radioactive wastes
H. Beikman (D)

*Storm Hill quadrangle
G. A. Izett (D)

*Quaternary geology of the Wind River Mountains
G. M. Richmond (D)

Chemical composition of thermal waters in Yellowstone Park
G. W. Morey (W)

Gravity studies; Yellowstone area
H. L. Baldwin (D)

Mineral resources:

*Green River formation, Sweetwater County (oil shale, salines)
W. C. Culbertson (D)

Williston Basin oil and gas studies, Wyoming, Montana, North Dakota, and South Dakota
C. A. Sandberg (D)

*Beaver Divide area (oil and gas)
F. B. Van Houten (Princeton, N.J.)

*Crowheart Butte area (oil and gas)
J. F. Murphy (W)

*Shotgun Butte (oil and gas)
W. R. Keefer (Laramie, Wyo.)

*Whalen-Wheatland area (oil and gas)
L. W. McGrew (Laramie, Wyo.)

Regional geology of the Wind River Basin (oil and gas)
W. R. Keefer (Laramie, Wyo.)

Wyoming—Continued
Mineral resources—Continued
*Atlantic City district (iron, gold)
R. W. Bayley (M)
Titaniferous black sands in Upper Cretaceous rocks
R. S. Houston (Laramie, Wyo.)
*Regional stratigraphic study of the Inyan Kara group, Black Hills (uranium)
W. J. Mapel (D)
Regional gravity studies in uranium geology, Black Hills area
R. M. Hazlewood (D)
Uranium and phosphate in the Green River formation
W. R. Keefer (Laramie, Wyo.)
*Baggs area, Wyoming and Colorado (uranium)
G. E. Prichard (D)
*Crooks Gap area, Fremont County (uranium)
J. G. Stephens (D)
*Gas Hills district (uranium)
H. D. Zeller (D)
*Hiland-Clarkson Hills area (uranium)
E. I. Rich (M)
Shirley basin area, (uranium)
E. N. Harshman (D)
*Southern Powder River basin (uranium)
W. N. Sharp (D)
*Pumpkin Buttes area, Powder River Basin (uranium)
W. N. Sharp (D)
*Western Red Desert area (uranium in coal)
G. N. Pipiringos (D)
Water resources:
Mining hydrology
W. T. Stuart (g, W)
Effects of sediment on the propagation of trout in small streams
A. R. Gustafson (q, Worland, Wyo.)
The effects of exposure on slope morphology
R. F. Hadley (h, D)
Northern and western Crook County (ground water)
H. A. Whitcomb (g, Cheyenne, Wyo.)
Johnson County (chemical quality of ground water)
T. R. Cummings (q, Worland, Wyo.)
Northern Johnson County (ground water)
R. A. McCullough (g, Cheyenne, Wyo.)
Niobrara County (ground water)
H. A. Whitcomb (g, Cheyenne, Wyo.)
Sheridan County (ground water)
M. E. Lowry (g, Cheyenne, Wyo.)
Sheridan County (chemical quality of ground water)
T. R. Cummings (q, Worland, Wyo.)
Cheyenne area (ground water)
E. D. Gordon (g, Cheyenne, Wyo.)
Devils Tower National Monument (ground water)
E. D. Gordon (g, Cheyenne, Wyo.)
Grand Teton National Park (ground water)
E. D. Gordon (g, Cheyenne, Wyo.)
Lyman-Mountain View area (ground water)
C. J. Robinove (g, Cheyenne, Wyo.)
Wheatland Flats area (ground water)
E. P. Weeks (g, Cheyenne, Wyo.)
Sedimentation and chemical quality of surface waters in the Wind River Basin
R. C. Williams (q, Worland, Wyo.)

Wyoming—Continued
Water resources—Continued
Bridge Bay, Yellowstone National Park (ground water)
E. D. Gordon (g, Cheyenne, Wyo.)
Puerto Rico and Caribbean area:
*Geology and mineral resources of Puerto Rico
W. H. Monroe (San Juan, Puerto Rico)
Carbonate sediments, Bahama Banks
P. E. Cloud (W)
Cenozoic faunas, Caribbean area
W. P. Woodring (W)
Recent Foraminifera, Central America
P. J. Smith (M)
Flood investigations, Puerto Rico
H. H. Barnes (s, Atlanta, Ga.)
Public water supplies in Puerto Rico
T. Arnow (g, San Juan, Puerto Rico)
Puerto Rico (surface water)
D. B. Bogart (s, San Juan, Puerto Rico)
Lower Tallaboa Valley, Puerto Rico (ground water)
I. G. Grossman (g, San Juan, Puerto Rico)
Guantanamo Bay, Cuba (ground water)
H. Sutcliffe (g, Tallahassee, Fla.)
Western Pacific Islands:
Cenozoic Foraminifera, Pacific Ocean and Islands
M. R. Todd (W)
Cenozoic gastropods and pelecypods, Pacific Islands
F. S. MacNeil (M)
Cenozoic mollusks, Pacific Islands
H. S. Ladd (W)
Pacific Islands vegetation
F. R. Fosberg (W)
*Bikini and nearby atolls
H. S. Ladd (W)
*Guam
J. I. Tracey, Jr. (W)
*Ishigaki, Ryukyu Islands
H. L. Foster (W)
Vertebrate faunas, Ishigaki Ryukyu Islands
F. C. Whitmore, Jr. (W)
Thermal and seismic studies in the Marshall Islands
J. H. Swartz (W)
*Okinawa
G. Corwin (W)
*Pagan Island
G. Corwin (W)
*Palau Islands
G. Corwin (W)
*Tinian
D. B. Doan (W)
*Truk
J. T. Stark (Recife, Brazil)
*Yap and Caroline Islands
C. G. Johnson (Honolulu, Hawaii)
Guam (ground water)
D. A. Davis (g, Honolulu, Hawaii)
Southern Okinawa (ground water)
D. A. Davis (g, Honolulu, Hawaii)
American Samoa (ground water)
K. J. Takasaki (g, Honolulu, Hawaii)
Tutuila, American Samoa (surface water)
H. H. Hudson (s, Honolulu, Hawaii)

Antarctica:
- Reconnaissance geology along the Eights and Walgreen Coasts
  - A. A. Drake, Jr. (W)
- Reconnaissance geology, eastern Horlick Mountain
  - E. L. Boudette (W)
- Reconnaissance geology, central Marie Byrd Land
  - E. L. Boudette (W)
- Reconnaissance geology, Thurston Peninsula
  - H. A. Hubbard (W)

Geologic and hydrologic investigations in other countries:
- Afghanistan—surface-water resources of Helmand River basin
  - R. H. Brigham (w, Lashkar Gah, Afghanistan)
- Argentina—governmental ground-water investigatory services (advisory)
  - S. L. Schoff (w, Buenos Aires, Argentina)
- Bolivia—mineral resources and geologic mapping (advising and training)
  - C. M. Tschanz (LaPaz, Bolivia)
- *Brazil—iron and manganese resources, Minas Gerais
  - J. V. N. Dorr II (Belo Horizonte, Brazil)
- *Brazil—base-metal resources
  - A. J. Bodenlos (Rio de Janeiro, Brazil)
- Brazil—geological education
  - A. J. Bodenlos (Rio de Janeiro, Brazil)
- Brazil—uranium resources (training)
  - C. T. Pierson (Rio de Janeiro, Brazil)
- Brazil—governmental ground-water investigatory services (advisory)
  - R. Schneider (w, Rio de Janeiro, Brazil)
- *Chile—mineral resources and national geologic mapping
  - R. J. Dingman (Santiago, Chile)
- Chile—ground-water investigations and hydrogeologic mapping
  - R. J. Dingman (w, Santiago, Chile)
- **Greenland, eastern—surficial geology (construction-site planning)
  - W. E. Davies (W)
- India—mineral resources (advisory)
  - L. V. Blade (Calcutta, India)
- Indonesia—economic and engineering geology (advisory and training)
  - R. F. Johnson (Bandung, Indonesia)
- Iran—nationwide river basin surveys
  - A. F. Pendleton (w, Teheran, Iran)
- **Libya—industrial minerals and national geologic map
  - G. H. Goudarzi (Tripoli, Libya)
- Libya—ground-water investigation and development
  - J. R. Jones (w, Benghazi, Libya)

Geologic and hydrologic investigations in other countries—Con.
- Mexico—training in regional geologic mapping
  - R. L. Miller (Mexico, D.F., Mexico)
- Netherlands—origin of salt ground water
  - J. E. Upson (g, Mineola, N.Y.)
- Pakistan—mineral resources development (advisory and training)
  - J. A. Reinemund (Quetta, Pakistan)
- Pakistan—ground-water investigations and hydrogeologic mapping
  - D. W. Greenman (w, Lahore, Pakistan)
- **Philippines—iron, chromite and nonmetallic mineral resources
  - J. F. Harrington (Manila, P.I.)
- Philippines—water-resources investigations (advisory)
  - C. R. Murray (w, Manila, P.I.)
- **Saudi Arabia—national geologic map
  - G. F. Brown (Jidda, Saudi Arabia)
- Southern Rhodesia—areal ground-water investigations (advisory)
  - P. E. Dennis (w, Salisbury, Southern Rhodesia)
- *Taiwan—economic geology (training)
  - S. Rosenblum (Taipei, Taiwan)
- Thailand—economic geology and mineral industry expansion (advisory)
  - L. S. Gardner (Bangkok, Thailand)
- Tunisia—ground-water investigations and hydrogeologic mapping
  - H. E. Thomas (w, Tunis, Tunisia)
- Turkey—Geological education, University of Istanbul (training)
  - Q. D. Singewald (Istanbul, Turkey)
- Turkey—nationwide surface-water investigations
  - C. C. Yonker (w, Ankara, Turkey)
- United Arab Republic (Egypt)—ground-water investigation of the western desert
  - H. A. Waite (w, Cairo, Egypt)

Extraterrestrial studies:
- Photogeology of the moon; lunar photometry
  - W. A. Fischer (W)
- Photogeology of the moon; stratigraphy and structure
  - R. J. Hackman (W)
- Terrane study of the moon
  - A. C. Mason (W)
- Mineralogy and petrology of meteorites and tektites
  - E. C. T. Chao (W)
- Chemistry of tektites
  - F. Cuttita (W)

TOPICAL INVESTIGATIONS

Heavy metals
District studies:
Ferrous and ferro-alloy metals:
*Selected iron deposits of the Northeastern States
A. F. Buddington (Princeton, N.J.)
Correlation of aeromagnetic studies and areal geology, Adirondacks area, New York (iron)
J. R. Balsley (W)
Correlation of aeromagnetic studies and areal geology, New York-New Jersey Highlands (iron)
A. Jespersen (W)
Clinton iron ores of the southern Appalachians
R. P. Sheldon (D)
*Iron River-Crystal Falls district, Michigan (iron)
H. L. James (M)
*Eastern Iron County, Michigan (iron)
K. L. Wier (Iron Mountain, Mich.)
*Southern Dickinson County, Michigan (iron)
R. W. Bayley (M)
*East Marquette district, Michigan (iron)
J. E. Gair (D)
*Florence County, Wisconsin (iron)
C. E. Dutton (Madison, Wis.)
*Cuyuna North Range, Minnesota (iron)
R. G. Schmidt (W)
Iron ore deposits of Nevada
R. G. Reeves (M)
*Atlantic City district, Wyoming (iron, gold)
R. W. Bayler (M)
*Unionville and Buffalo Mountain quadrangles, Humboldt Range, Nevada (iron, tungsten, silver, quicksilver)
R. E. Wallace (M)
Ore deposits of southwestern Montana
H. L. James (M)
**Klukwan iron district, Alaska
E. C. Robertson (W)
*Southeastern Aroostook County, Maine (manganese)
L. Pavlides (W)
Manganese deposits of the Philipsburg area, Montana (manganese and base metals)
W. C. Prinz (Spokane, Wash.)
*John Day area, Oregon (chromite)
T. P. Thayer (W)
Lateritic nickel deposits of the Klamath Mountains, Oregon-California
P. E. Hotz (M)
*Hamme tungsten deposit, North Carolina
J. M. Parker, 3d (Raleigh, N.C.)
*Wheeler Peak and Garrison quadrangles, Snake Range, Nevada and Utah (tungsten and beryllium)
D. H. Whitebread (M)
*Osgood Mountains quadrangle, Nevada (tungsten, quicksilver)
P. E. Hotz (M)
*Bishop tungsten district, California
P. C. Bateman (M)
*Eastern Sierra tungsten area, California; Devil's Postpile, Mt. Morrison, and Casa Diablo quadrangles (tungsten, base metals)
C. D. Rinehart (M)

Heavy metals—Continued
District studies—Continued
Ferrous and ferro-alloy metals—Continued
*Geologic study of the Sierra Nevada batholith, California (tungsten, gold, base metals)
P. C. Bateman (M)
*Blackbird Mountain area, Idaho (cobalt)
J. S. Vhay (Spokane, Wash.)
*Quartzburg district, Oregon (cobalt)
J. S. Vhay (Spokane, Wash.)
*Thunder Mountain niobium area, Montana-Idaho
R. L. Parker (D)
Magnet Cove niobium investigations, Arkansas
L. V. Blade (Paducah, Ky.)
Base and precious metals:
*Swain County copper district, North Carolina
G. H. Espenshade (W)
Massive sulfide deposits of the Ducktown district, Tennessee and adjacent areas (copper, iron, sulfur)
R. M. Hernon (D)
*Michigan copper district
W. S. White (W)
Copper deposits in sandstone
C. B. Read (Albuquerque, N. Mex.)
*Silver City region, New Mexico (copper, zinc)
W. R. Jones (D)
*Bradshaw Mountains, Arizona (copper)
C. A. Anderson (W)
*Christmas quadrangle, Arizona (copper, iron)
C. R. Willden (M)
*Globe-Miami area, Arizona (copper)
N. P. Peterson (Globe, Ariz.)
*Klondyke quadrangle, Arizona (copper)
F. S. Simons (D)
Contact-metamorphic deposits of the Little Dragoons area, Arizona (copper)
J. R. Cooper (D)
*Mammoth and Benson quadrangles, Arizona (copper)
S. C. Creasey (M)
*Prescott-Paulden area, Arizona (copper)
M. H. Krieger (M)
*Twin Buttes area, Arizona (copper)
J. R. Cooper (D)
*Regional geologic setting of the Bingham Canyon district, Utah (copper)
R. J. Roberts (M)
*Regional geologic setting of the Ely district, Nevada (copper, lead, zinc)
A. L. Brokaw (D)
*Lyon, Douglas, and Ormsby Counties, Nevada (copper)
J. G. Moore (M)
Structural geology of the Sierra foothills mineral belt, California (copper, zinc, gold, chromite)
L. D. Clark (M)
*Holden and Lucerne quadrangles, Northern Cascade Mountains, Washington (copper)
F. W. Cater (D)
**Southern Brooks Range, Alaska (copper, precious metals)
W. P. Brosgé (M)

Heavy metals—Continued
District studies—Continued
Base and precious metals—Continued
*Central City-Georgetown area, Colorado, including studies of the Precambrian history of the Front Range (base, precious, and radioactive metals)
P. K. Sims (D)
Volcanic and economic geology of the Creede caldera, Colorado (base and precious metals, fluorspar)
T. A. Steven (D)
*Tenmile Range, including the Kokomo mining district, Colorado (base and precious metals)
A. H. Koschmann (D)
*San Francisco Mountains, Utah (base metals, tungsten)
D. M. Lemmon (M)
*Antler Peak quadrangle, Nevada (base and precious metals)
R. J. Roberts (M)
*Eureka County, Nevada (base and precious metals)
R. J. Roberts (M)
*Boulder batholith area, Montana (base, precious, and radioactive metals)
M. R. Klepper (W)
*East Tennessee zinc studies
A. L. Brokaw (D)
Origin and depositional control of some Tennessee and Virginia zinc deposits
H. Wedow, Jr. (Knoxville, Tenn.)
*Wisconsin zinc-lead mining district
J. W. Whitlow (D)
*Stratigraphy of the lead-zinc district near Dubuque, Iowa
J. W. Whitlow (W)
*Lead deposits of southeastern Missouri
T. H. Kiilsgaard (W)
Tri-State lead-zinc district, Oklahoma, Missouri, Kansas
E. T. McKnight (W)
*Holy Cross quadrangle, Colorado, and the Colorado mineral belt (lead, zinc, silver, copper, gold)
O. Tweto (D)
*Minturn quadrangle, Colorado (zinc, silver, copper, lead, gold)
T. S. Lovering (D)
*Rico district, Colorado (lead, zinc, silver)
E. T. McKnight (W)
*San Juan mining area, Colorado, including detailed study of the Silverton Caldera (lead, zinc, silver, gold, copper)
R. G. Luedke (W)
*Alta quadrangle, Utah (lead, silver, phosphate rock)
M. D. Crittenden, Jr. (M)
*East Tintic lead-zinc district, Utah, including extensive geochemical studies
H. T. Morris (M)
*Eureka area, Nevada (zinc, lead, silver, gold)
T. B. Nolan (W)
Ione quadrange, Nevada (lead, quicksilver, tungsten)
C. J. Vitaliano (Bloomington, Ind.)
Ore deposits of the Coeur d'Alene mining district, Idaho (lead, zinc, silver)
V. C. Fryklund, Jr. (Spokane, Wash.)

Heavy metals—Continued
District studies—Continued
Base and precious metals—Continued
*General geology of the Coeur d'Alene mining district, Idaho (lead, zinc, silver)
A. B. Griggs (M)
*New York Butte quadrangle, California (lead-zinc)
W. C. Smith (M)
*Panamint Butte quadrangle, California, including special geochemical studies (lead-silver)
W. E. Hall (W)
*Metaline lead-zinc district, Washington
M. G. Dings (D)
*Stevens County, Washington, lead-zinc district
R. G. Yates (M)
*Mt. Diablo area, California (quicksilver, copper, gold, silver)
E. H. Pampeyan (M)
*Ochoco Reservation, Lookout Mountain, Eagle Rock, and Post quadrangles, Oregon (quicksilver)
A. C. Waters (Baltimore, Md.)
**Lower Kuskokwim-Bristol Bay region, Alaska (quicksilver, antimony, zinc)
J. M. Hoare (M)
Quicksilver deposits, southwestern Alaska
E. M. MacKevett, Jr. (M)
*Nome C–1 and D–1 quadrangles, Alaska (gold)
C. L. Hummel (M)
*Tofty placer district, Alaska (gold, tin)
D. M. Hopkins (M)
**Regional geology and mineral resources, southeastern Alaska
R. A. Loney (M)
Seward Peninsula tin investigations, Alaska
P. L. Killeen (W)
Commodity and topical studies:
Mineral resource information and research
H. Kirkemo (W)
U.S. Mineral Resource maps
W. L. Newman (W)
Mineral exploration, northwestern United States
D. R. MacLaren (Spokane, Wash.)
Resource study and appraisal of ferrous and ferro-alloy metals
T. P. Thayer (W)
Resource study and appraisal of base and precious metals
A. R. Kinkel, Jr. (W)
Resources and geochemistry of rare-earth elements
J. W. Adams (D)
Refractory metals resources
V. C. Fryklund, Jr. (Spokane, Wash.)
Tantalum-niobium resources of the United States
R. L. Parker (D)
Western oxidized zinc deposits
A. V. Heyl (W)
Origin of the Mississippi Valley type ore deposits
A. V. Heyl (W)
Massive sulfide deposits
A. R. Kinkel, Jr. (W)
Alaskan metallogenic provinces
C. L. Sainsbury (M)
Miscellaneous mineral resource investigations, Alaska
E. M. MacKevett, Jr. (M)

Light metals and industrial minerals:
District studies:
Titaniferous black sands in Upper Cretaceous rocks, Wyoming
R. S. Houston (Laramie, Wyo.)
*Marysvale district, Utah (alunite)
R. L. Parker (D)
*McFadden Peak and Blue House Mountain quadrangles, Arizona (asbestos)
A. F. Shride (D)
*Talc and asbestos deposits of north-central Vermont
W. M. Cady (Montpelier, Vt.)
Barite deposits of Arkansas
D. A. Brobst (D)
Bauxite deposits of the southeastern States
E. F. Overstreet (W)
Aeromagnetic studies in the Newport, Arkansas, and Ozark bauxite areas
A. Jespersen (W)
*Greenacres quadrangle, Washington-Idaho (high-alumina clays)
P. L. Weis (Spokane, Wash.)
High-alumina weathered basalt on Kauai, Hawaii
S. H. Patterson (W)
Clay deposits of Maryland
M. M. Knechtel (W)
Clay deposits of the Olive Hill bed of eastern Kentucky
J. W. Hosterman (W)
Clay studies, Colorado Plateau
L. G. Schultz (D)
*Lake George district, Colorado (beryllium)
C. C. Hawley (D)
Fluorspar deposits of northwestern Kentucky
R. D. Trace (Princeton, Ky.)
*Salem quadrangle, Kentucky (fluorspar)
R. D. Trace (Princeton, Ky.)
*Poncha Springs and Saguache quadrangles, Colorado (fluorspar)
R. E. Van Alstine (W)
Thomas and Dugway Ranges, Utah (fluorspar-beryllium)
M. H. Staatz (D)
*Beatty area, Nevada (fluorite, bentonite, gold, silver)
H. R. Cornwall (M)
*Western Mojave Desert, California (boron)
T. W. Dibblee, Jr. (M)
*Furnace Creek area, California (boron)
J. F. McAllister (M)
Origin of the borate-bearing marsh deposits of California, Oregon, and Nevada (boron)
W. C. Smith (M)
*Geology and origin of the saline deposits of Searles Lake, California
G. I. Smith (M)
Potash and other saline deposits of the Carlsbad area, New Mexico
C. L. Jones (M)
*Heceta-Tuxekan area, Alaska (high-calcium limestone)
G. D. Eberlein (M)
*Chewelah area, Washington (magnesite)
I. Campbell (San Francisco, Calif.)
*Hunters quadrangle, Washington (magnesite, tungsten, base metals, barite)
A. B. Campbell (D)

Light metals and industrial minerals—Continued
District studies—Continued
Pegmatites of the Spruce Pine and Franklin-Sylva districts, North Carolina
F. G. Lesure (Knoxville, Tenn.)
*Geologic setting of the Spruce Pine pegmatite district, North Carolina (mica, feldspar)
D. A. Brobst (D)
*Southern Black Hills, South Dakota (pegmatite minerals)
J. J. Norton (W)
*Pegmatites of the Custer district, South Dakota
J. A. Redden (Blacksburg, Va.)
*Structure and metamorphism, Hill City quadrangle, South Dakota (pegmatite minerals)
J. C. Ratté (D)
Phosphate deposits of northern Florida
G. H. Espenshade (W)
*Florida land-pebble phosphate deposits
J. B. Cathcart (D)
Stratigraphy and resources of the Phosphoria formation in Idaho (phosphate, minor elements)
V. E. McKelvey (W)
*Aspen Range-Dry Ridge area, Idaho (phosphate)
V. E. McKelvey (W)
*Soda Springs quadrangle, Idaho, including studies of the Bannock thrust zone (phosphate)
F. C. Armstrong (Spokane, Wash.)
Stratigraphy and resources of Permian rocks in western Wyoming (phosphate, minor elements)
R. P. Sheldon (D)
Phosphate deposits of south-central Montana
R. W. Swanson (Spokane, Wash.)
Stratigraphy and resources of the Phosphoria and Park City formations in Utah and Nevada (phosphate, minor elements)
K. M. Tagg (M)
Commodity and topical studies:
Resource study and appraisal, light metals and industrial minerals
J. J. Norton (W)
Resources and geochemistry of selenium in the United States
D. F. Davidson (D)
Phosphate reserves, Southeastern United States
J. B. Cathcart (D)
Geochemistry and petrology of western phosphate deposits
R. A. Gulbrandsen (M)
Radioactive minerals:
District studies:
Geology of the Piedmont region of the Southeastern States (monazite)
W. C. Overstreet (W)
*Shelby quadrangle (monazite)
W. C. Overstreet (W)
*Radioactive placer deposits of central Idaho
D. L. Schmidt (Seattle, Wash.)
*Powderhorn area, Gunnison County, Colorado (thorium)
J. C. Olson (D)
*Wet Mountains, Colorado (thorium, base and precious metals)
M. R. Brock (W)

Radioactive minerals—Continued
District studies—Continued
Selected studies of uranium deposits in Pennsylvania
H. Klemic (W)
*Lehighton quadrangle, Pennsylvania (uranium)
H. Klemic (W)
Mineralogy of uranium-bearing rocks in Karnes and Duval Counties, Texas
A. D. Weeks (W)
*Harding County, South Dakota, and adjacent areas (uraniferous lignite)
G. N. Pipiringos (D)
*Western Red Desert area, Wyoming (uranium in coal)
G. N. Pipiringos (D)
*Southern Black Hills, South Dakota (uranium)
G. B. Gott (D)
Regional gravity studies in uranium geology, Black Hills area
R. M. Hazelwood (D)
*Regional stratigraphic study of the Inyan Kara group, Black Hills, Wyoming (uranium)
W. J. Mapel (D)
Uranium and phosphate in the Green River formation, Wyoming
W. R. Keefer (Laramie, Wyo.)
*Baggs area, Wyoming and Colorado (uranium)
G. E. Prichard (D)
*Crooks Gap area, Fremont County, Wyoming (uranium)
J. G. Stephens (D)
*Gas Hills district, Wyoming (uranium)
H. D. Zeller (D)
*Hiland-Clarkson Hills area, Wyoming (uranium)
E. I. Rich (M)
*Pumpkin Buttes area, Powder River Basin, Wyoming (uranium)
W. N. Sharp (D)
*Southern Powder River Basin, Wyoming (uranium)
W. N. Sharp (D)
Shirley basin area, Wyoming (uranium)
E. N. Harshman (D)
*Storm Hill quadrangle, Wyoming (uranium)
G. A. Izett (D)
*Uranium deposits in the Front Range, Colorado
P. K. Sims (D)
**Compilation of Colorado Plateau geologic maps (uranium, vanadium)
D. G. Wyant (D)
Colorado Plateau botanical prospecting studies
F. J. Kleinhampl (M)
Triassic stratigraphy and lithology of the Colorado Plateau (uranium, copper)
J. H. Stewart (D)
San Rafael group stratigraphy, Colorado Plateau (uranium)
J. C. Wright (D)
*Bull Canyon district, Colorado (vanadium, uranium)
C. H. Roach (D)
Exploration for uranium deposits in the Gypsum Valley district, Colorado
C. F. Withington (W)
*Klondike Ridge area, Colorado (uranium, copper, manganese, salines)
J. D. Vogel (D)

Radioactive minerals—Continued
District studies—Continued
*Maybell-Lay area, Moffat County, Colorado (uranium)
M. J. Bergin (W)
*Ralston Buttes, Colorado (uranium)
D. M. Sheridan (D)
*Western San Juan Mountains, Colorado (uranium, vanadium, gold)
A. L. Bush (W)
*Slick Rock district, Colorado (uranium, vanadium)
D. R. Shawe (D)
Uravan district, Colorado (vanadium, uranium)
R. L. Boardman (W)
*Ute Mountains, Colorado (uranium, vanadium)
E. B. Ekren (D)
Regional relations of the uranium deposits of northwestern New Mexico
L. S. Hilpert (Salt Lake City, Utah)
Ambrosia Lake district, New Mexico (uranium)
H. C. Granger (D)
*Grants area, New Mexico (uranium)
R. E. Thaden (Columbia, Ky.)
Mineralogy of uranium-bearing rocks in the Grants area, New Mexico
A. D. Weeks (W)
*Laguna district, New Mexico (uranium)
R. H. Moench (D)
*Tucumcari-Sabinoso area, New Mexico (uranium)
R. L. Griggs (D)
*Abajo Mountains, Utah (uranium, vanadium)
I. J. Witkind (D)
*Circle Cliffs area, Utah (uranium)
E. S. Davidson (Tucson, Ariz.)
*Elk Ridge area, Utah (uranium)
R. Q. Lewis (D)
*Deer Flat area, White Canyon district, Utah (uranium, copper)
T. L. Finnell (D)
*La Sal area, Utah-Colorado (uranium, vanadium)
W. D. Carter (Santiago, Chile)
*Lisbon Valley area, Utah-Colorado (uranium, vanadium, copper)
G. W. Weir (M)
*Moab-Interriver area, east-central Utah (uranium)
E. N. Hinrichs (D)
*Orange Cliffs area, Utah (uranium)
F. A. McKeown (D)
*Sage Plain area, Utah (uranium and vanadium)
L. C. Huff (D)
Uranium ore controls of the San Rafael Swell, Utah
C. C. Hawley (D)
*White Canyon area, Utah (uranium, copper)
R. E. Thaden (D)
Studies of uranium deposits in Arizona
H. C. Granger (D)
*Carrizo Mountains area, Arizona-New Mexico (uranium)
J. D. Strobell (D)
Uranium deposits of the Dripping Spring quartzite of southeastern Arizona
H. C. Granger (D)

Radioactive minerals—Continued
District studies—Continued
*East Vermillion Cliffs area, Arizona (uranium, vanadium)
R. G. Peterson (Boston, Mass.)
*Mt. Spokane quadrangle, Washington (uranium)
A. E. Weissenborn (Spokane, Wash.)
*Turtle Lake quadrangle, Washington (uranium)
G. E. Becraft (D)
Commodity and topical studies:
Resource studies and appraisals of radioactive raw materials
A. P. Butler (D)
Geology of monazite
W. C. Overstreet (W)
Uranium deposits in sandstone
W. I. Finch (D)
Processes of formation and redistribution of uranium deposits
K. G. Bell
Relative concentrations of chemical elements in rocks and ore deposits of the Colorado Plateau (uranium, vanadium, copper)
A. T. Miesch (D)
Uranium-vanadium deposits in sandstone, with emphasis on the Colorado Plateau
R. P. Fischer (D)
Uranium in natural waters
P. W. Fix (W)
Trace elements in rocks of Pennsylvanian age (uranium, phosphate)
W. Danilchik (Quetta, Pakistan)
Uranium-thorium reconnaissance, Alaska
E. M. MacKevett, Jr. (M)
Fuels:
District studies:
Petroleum and natural gas:
*Stratigraphy of the Dunkirk and related beds in the Penn Yan and Keuka Lake quadrangles, New York (oil and gas)
M. J. Bergin (W)
*Stratigraphy of the Dunkirk and related beds, in the Bath and Woodhull quadrangles, New York (oil and gas)
J. F. Pepper (New Philadelphia, Ohio)
*Northern Arkansas oil and gas investigations, Arkansas
E. E. Glick (D)
Central Nebraska basin (oil and gas)
G. E. Prichard (D)
Subsurface geology of Dakota sandstone, Colorado and Nebraska (oil and gas)
N. W. Bass (D)
Paleozoic stratigraphy of the Sedgwick Basin, Kansas (oil and gas)
W. L. Adkison (Lawrence, Kans.)
*Shawnee County, Kansas (oil and gas)
W. D. Johnson, Jr. (Lawrence, Kans.)
*Wilson County, Kansas (oil and gas)
H. C. Wagner (M)
McAlester Basin, Oklahoma (oil and gas)
S. E. Frezon (D)
Anadarko Basin, Oklahoma and Texas (oil and gas)
W. L. Adkison (Lawrence, Kans.)

Fuels—Continued
District studies—Continued
Petroleum and natural gas—Continued
*Wayland quadrangle, Texas (oil and gas investigations)
D. A. Myers (D)
*Franklin Mountains, New Mexico and Texas (petroleum)
R. L. Harbour (D)
Oil and gas fields, New Mexico
D. C. Duncan (W)
Williston Basin oil and gas studies, Wyoming, Montana, North Dakota, South Dakota
C. A. Sandberg (D)
*Geology of the Winnett-Mosby area, Montana (oil and gas)
W. D. Johnson, Jr. (Lawrence, Kans.)
*Beaver Divide area, Wyoming (oil and gas)
F. B. Van Houten (Princeton, N.J.)
*Crowheart Butte area, Wyoming (oil and gas)
J. F. Murphy (D)
*Shotgun Butte, Wyoming (oil and gas)
W. R. Keefer (Laramie, Wyo.)
*Whalen-Wheatland area, Wyoming (oil and gas)
L. W. McGrew (Laramie, Wyo.)
Regional geology of the Wind River Basin, Wyoming (oil and gas)
W. R. Keefer (Laramie, Wyo.)
*Fuels potential of the Navajo Reservation, Arizona and Utah
R. B. O'Sullivan (D)
*Eastern Los Angeles basin, California (petroleum)
J. E. Schoellhamer (M)
*Southeastern Ventura Basin, California (petroleum)
E. L. Winterer (Los Angeles, Calif.)
*Northwest Sacramento Valley, California (petroleum)
R. D. Brown, Jr. (M)
*Anlauf and Drain quadrangles, Oregon (oil and gas)
L. Hoover (W)
**Nelchina area, Alaska (petroleum)
A. Grantz (M)
*Iniskin-Tuxedni region, Alaska (petroleum)
R. L. Detterman (M)
**Gulf of Alaska province, Alaska (petroleum)
D. J. Miller (M)
**Lower Yukon-Koyukuk area, Alaska (petroleum)
W. W. Patton, Jr. (M)
**Northern Alaska petroleum investigations
G. Gryc (W)
Coal:
*Warrior quadrangle, Alabama (coal)
W. C. Culbertson (D)
Coal resources of Alabama
W. C. Culbertson (D)
*Ivydell, Pioneer, Jellico West, and Ketchen quadrangles, Tennessee (coal)
K. J. Englund (W)
*Allegany County, Maryland (coal)
W. deWitt, Jr. (W)
*Bituminous coal resources of Pennsylvania
E. D. Patterson (W)
Washington County, Pennsylvania (coal)
H. Berryhill, Jr. (D)
*Southern anthracite field, Pennsylvania
G. H. Wood, Jr. (W)

Fuels—Continued
District studies—Continued
Coal—Continued
*Western middle anthracite coal field, Pennsylvania
H. H. Arndt (W)
*Geology and coal resources of Belmont County, Ohio
H. L. Berryhill, Jr. (D)
*Eastern Kentucky coal investigations, Kentucky
J. W. Huddle (W)
*Ft. Smith district, Arkansas and Oklahoma (coal and gas)
T. A. Hendricks (D)
*Arkansas Basin coal investigations
B. R. Haley (D)
*Animas River area, Colorado and New Mexico (coal, oil, and gas)
H. Barnes (D)
*Carbondale coal field, Colorado
J. R. Donnell (D)
*Eastern North Park, Colorado (coal, oil, and gas)
D. M. Kinney (W)
*Western North Park, Colorado (coal, oil, and gas)
W. J. Hail (D)
*Trinidad coal field, Colorado
R. B. Johnson (D)
*Raton Basin coking coal, New Mexico
G. H. Dixon (M)
*East side San Juan Basin, New Mexico (coal, oil and gas)
C. H. Dane (W)
*Cedar Mountain quadrangle, Iron County, Utah (coal)
P. Averitt (D)
*Southern Kolob Terrace coal field, Utah
W. B. Cashion (D)
*Geology of the Livingston-Trail Creek area, Montana (coal)
A. E. Roberts (D)
Coal resources of Washington
H. D. Gower (M)
*Maple Valley, Hobart and Cumberland quadrangles, King County, Washington (coal)
J. D. Vine (M)
*Beluga-Yentna area, Alaska (coal)
F. F. Barnes (M)
*Matanuska coal field, Alaska
F. F. Barnes (M)
*Matanuska stratigraphic studies, Alaska (coal)
A. Grantz (M)
*Nenana coal investigations, Alaska
C. Wahrhaftig (M)
Oil shale:
**Oil shale investigations in Colorado
D. C. Duncan (W)
*Grand-Battlement Mesa oil-shale, Colorado
J. R. Donnell (D)
*Uinta Basin oil shale, Utah
W. B. Cashion (D)
*Green River formation, Sweetwater County, Wyoming (oil shale, salines)
W. C. Culbertson (D)
Resource studies:
Fuel resource studies
D. C. Duncan (W)
Geology of the continental shelves
J. F. Pepper (New Philadelphia, Ohio)

Fuels—Continued
Resource studies—Continued
Synthesis of geologic data on Atlantic Coastal Plain and Continental Shelf
J. E. Johnston (W)
Water:
Regional and district studies:
Columbia River basalt hydrology
R. C. Newcomb (g, Portland, Oreg.)
Limestone terrane hydrology
W. J. Powell (g, Tuscaloosa, Ala.)
Water-supply exploration on the public domain (Western States)
G. G. Parker (h, D)
Hydrologic effect of urbanization
A. O. Waananen (h, M)
North Pacific Coast area (surface water)
E. E. Harris (s, M)
Local floods, Alabama
L. B. Peirce (s, Montgomery, Ala.)
Rillito basin, Arizona (surface water)
J. J. Ligner (s, Tucson, Ariz.)
Low-flow gaging, Arkansas
J. D. Warren (s, Fort Smith, Ark.)
Flood investigations, Arkansas
R. C. Christensen (s, Fort Smith, Ark.)
Floods from small areas in California
L. E. Young (s, M)
Escambia and Santa Rosa Counties, Florida (surface water)
R. H. Musgrove (s, Ocala, Fla.)
Polk County, Florida (surface water)
R. C. Heath (s, Ocala, Fla.)
Drought of 1954–56 in Florida
R. W. Pride (s, Ocala, Fla.)
Hillsborough River floods of 1960, Florida
R. W. Pride (s, Ocala, Fla.)
St. Johns, Flagler, and Putnam Counties, Florida (surface water)
W. E. Kenner (s, Ocala, Fla.)
Everglades National Park (surface water)
J. H. Hartwell (s, Ocala, Fla.)
Green Swamp area, Florida (surface water)
R. W. Pride (s, Ocala, Fla.)
Flood gaging, Georgia
C. M. Bunch (s, Atlanta, Ga.)
Lake mapping and stabilization, Indiana (surface water)
D. C. Perkins (s, Indianapolis, Ind.)
Floods from small areas, Iowa
H. H. Schwob (s, Iowa City, Iowa)
Eastern Kentucky (surface water)
G. A. Kirkpatrick (s, Louisville, Ky.)
Flood investigations, Louisiana
L. V. Page (s, Baton Rouge, La.)
Rifle River basin, Michigan (surface water)
R. W. Larson (s, Lansing, Mich.)
North Branch Clinton River basin, Michigan (surface water)
S. W. Wiitala (s, Lansing, Mich.)
Sloan and Deer Creek basins, Michigan (surface water)
L. E. Stoimenoff (s, Lansing, Mich.)

Water—Continued
Regional and district studies—Continued
Floods from small basins, Mississippi
K. V. Wilson (s, Jackson, Miss.)
Flood investigations on small areas, Missouri
E. H. Sandhaus (s, Rolla, Mo.)
Natural flow appraisals, Montana (surface water)
W. A. Blenkarn (s, Helena, Mont.)
Floods from small areas, Montana
F. C. Boner (s, Helena, Mont.)
Peak discharges from small areas, Nebraska
E. W. Beckman (s, Lincoln, Nebr.)
Hydrology of a portion of the Humboldt River Valley
T. W. Robinson (h, M)
Flood and base-flow gaging, New Jersey
E. G. Miller (s, Trenton, N.J.)
Babylon-Islip area, New York (surface water)
E. J. Pluhowski (s, Albany, N.Y.)
Small streams, New York (surface water)
O. P. Hunt (s, Albany, N.Y.)
Flood and low-flow gaging, Rockland County
G. R. Ayer (s, Albany, N.Y.)
Flood gaging, North Carolina
H. G. Hinson (s, Raleigh, N.C.)
Peak discharges from small areas, North Dakota
O. A. Crosby (s, Bismarck, N. Dak.)
Flood investigations, Puerto Rico
H. H. Barnes (s, Atlanta, Ga.)
Puerto Rico (surface water)
D. B. Bogart (s, San Juan, Puerto Rico)
Flood gaging, South Carolina
W. W. Evett (s, Columbia, S.C.)
Peak discharges from small areas, South Dakota
R. E. West (s, Pierre, S. Dak.)
Brazos River saline investigations
J. O. Joerns (s, Austin, Tex.)
Flood gaging, Utah
V. K. Berwick (s, Salt Lake City, Utah)
Flood investigations, Virginia
C. W. Lingham (s, Charlottesville, Va.)
Nooksack River basin, Washington (water)
E. G. Bailey (s, Tacoma, Wash.)
Kitsap Peninsula, Washington (surface water)
E. G. Bailey (s, Tacoma, Wash.)
Tutuila, American Samoa (surface water)
H. H. Hudson (s, Honolulu, Hawaii)
Water use:
Water use in the United States, 1960
K. E. MacKichan (h, W)
Water resources of entire states
K. E. MacKichan (h, W)
Water resources of selected industrial areas (nationwide)
O. D. Mussey (h, W)
Water requirements of selected industries (nationwide)
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Water requirements of the magnesium industry
O. D. Mussey (h, W)
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O. D. Mussey (h, W)
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O. D. Mussey (h, W)
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O. D. Mussey (h, W)

Paleontology:
Systematic paleontology:
Fossil wood and general palebotany
R. A. Scott (D)
Paleozoic paleobotany
S. H. Mamay (W)
Coal lithology and paleobotany
J. M. Schopf (Columbus, Ohio)
Upper Paleozoic floral zones and provinces
C. B. Read (Albuquerque, N. Mex.)
Lower Pennsylvanian floras of Illinois and adjacent States
C. B. Read (Albuquerque, N. Mex.)
Stratigraphic significance of the genus *Tempskya* in southwestern New Mexico
C. B. Read (Albuquerque, N. Mex.)
Post-Paleozoic pollen and spores
E. B. Leopold (D)
Diatom studies
K. E. Lohman (W)
Tertiary paleobotanical studies
J. A. Wolfe (M)
Marine paleoecology
P. E. Cloud, Jr. (W)
Vertebrate paleontologic studies, Western United States
G. E. Lewis (D)
Vertebrate faunas, Martha's Vineyard, Massachusetts
F. C. Whitmore, Jr. (W)
Vertebrate paleontology, Big Bone Lick, Kentucky
F. C. Whitmore, Jr. (W)
Vertebrate faunas, Ishigaki, Ryukyu Islands
F. C. Whitmore, Jr. (W)
Lower Paleozoic corals
W. A. Oliver, Jr. (W)
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W. J. Sando (W)
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H. Duncan (W)
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M. Gordon (M)
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E. L. Yochelson (W)
Cenozoic gastropods and pelecypods, Pacific Islands
F. S. MacNeil (M)
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F. S. MacNeil (M)
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I. G. Sohn (W)
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M. C. Israelsky (M)
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R. C. Douglass (W)
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Cenozoic faunas, Caribbean area
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Cambrian faunas and stratigraphy
A. R. Palmer (W)
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R. B. Neuman (W)
Ordovician stratigraphic paleontology of the Great Basin and Rocky Mountains
R. J. Ross, Jr. (D)
Subsurface Paleozoic rocks of Florida
J. M. Berdan (W)
Silurian and Devonian stratigraphic paleontology of the Great Basin and Pacific Coast
C. W. Merriam (W)
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E. R. Landis (D)
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J. T. Dutro, Jr. (W)
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C. P. Ross (D)
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W. A. Cobban and G. R. Scott (D)
Stratigraphic studies, Colorado Plateau (uranium, vanadium)
L. C. Craig (D)
*Geology and paleontology of the Cuyama Valley area, California
J. G. Vedder (M)
Mesozoic stratigraphic paleontology, Atlantic and Gulf coasts
N. F. Sohl (W)
Mesozoic stratigraphic paleontology of northwestern Montana
W. A. Cobban (D)
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Lower Mesozoic stratigraphy and paleontology, Humboldt Range, Nevada
N. J. Silberling (M)

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N. J. Silberling (M)
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R. W. Imlay (W)
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W. A. Cobban (D)
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Stratigraphy of the Trent marl and related units
P. M. Brown (g, Raleigh, N.C.)
Geomorphology and plant ecology:
The effects of exposure on slope morphology
R. F. Hadley (h, D)
Use of plant species or communities as indicators of soil moisture availability
F. A. Branson (h, D)
Interrelationships between ion distribution and water movement in soils and the associated vegetation
R. F. Miller (h, D)
Vegetation map of Alaska
L. A. Spetzman (W)
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Meandering valleys and related questions of Pleistocene chronology
G. H. Dury (w, W)
The hydraulic geometry of a small tidal estuary
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Evolution of Black Earth Creek and Mounds Creek, Wisconsin
G. H. Dury (w, W)
Clastic sedimentation in a bolson environment
L. K. Lustig (q, Boston, Mass.)
A study of stream gravel and gravel bars
L. B. Leopold (w, W)
Particle movement and channel scour and fill of an ephemeral arroyo near Santa Fe, N. Mex.
L. B. Leopold (w, W)
Bankfull discharge, with particular reference to certain channel dimensions
G. H. Dury (w, W)
Exploration of valley fills by seismic refraction
G. H. Dury (w, W)
Channel geometry studies, Iowa (surface water)
H. H. Schwob (s, Iowa City, Iowa)
Stream profiles, Alabama (surface water)
L. B. Peirce (s, Montgomery, Ala.)
Flood profiles, Iowa
H. H. Schwob (s, Iowa City, Iowa)
Geomorphology of glacier streams
R. K. Fahnestock (h, Fort Collins, Colo.)
Solution subsidence of a limestone terrane in southwest Georgia
S. M. Herrick (g, Atlanta, Ga.)
Hydrologic zonation of limestone formations
H. E. LeGrand (w, W)
Geomorphology in relation to ground water
H. E. LeGrand (w, W)

Geomorphology and plant ecology—Continued
Diagenesis and hydrologic history of the Tertiary limestone of North Carolina
H. E. LeGrand (w, W)
River systems studies
M. T. Thomson (s, Atlanta, Ga.)
Relation of geology to low flow, Georgia
O. J. Cosner (s, Atlanta, Ga.)
Basic research in vegetation and hydrology
R. S. Sigafoos (h, W)

Glaciology and glacial geology:
Recognition of late glacial substages in New England and New York
J. E. Upson (g, Mineola, N.Y.)
Glacialogical research
M. F. Meier (h, Tacoma, Wash.)

Permafrost studies:
Distribution and general characteristics of permafrost
W. E. Davies (W)
Relationship of permafrost to ground water
J. R. Williams (g, Anchorage, Alaska)
Arctic ice and permafrost studies, Alaska
A. H. Lachenbruch (M)
Origin and stratigraphy of ground ice in central Alaska
T. L. Péwé (College, Alaska)

Paleomagnetism:
Investigation of remanent magnetization of rocks
R. R. Doell (M)

Physical properties of rocks:
Rock behavior at high temperature and pressure
E. C. Robertson (W)
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L. Peselnick (W)
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F. E. Senftle (W)
Measurement of magnetic properties of rocks
W. E. Huff (W)
Magnetic properties of rocks
A. Griscom (W)
Electrical properties of rocks
C. J. Zablocki (D)
Infrared and ultraviolet radiation studies
R. M. Moxham (W)

Rock deformation:
Origin and mechanics of detachment faults
W. G. Pierce (M)
Impact metamorphism
E. C. T. Chao (W)
Experimental hyper-velocity impact studies
H. J. Moore (M)
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C. H. Roach (D)
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Geophysical exploration methods:
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R. G. Henderson (W)

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Physical and chemical contrasts between uranium-bearing sandstones and contiguous sandstones
G. E. Manger (W)
Electronics laboratory
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Measurement of background radiation:
Aerial radiological monitoring surveys, Northeastern United States
P. Popenoe (W)
Aerial radiological monitoring surveys, Belvoir area, Virginia and Maryland
S. K. Neuschel (W)
Aerial radiological monitoring surveys, Oak Ridge National Laboratory, Tennessee
R. G. Bates (W)
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J. A. MacKallor (W)
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Propagation of seismic waves in porous media.
J. A. daCosta (g, W)

Crustal studies:
- Thermal studies (earth temperatures)
  - H. C. Spicer (W)
- Seismic investigations of continental crust
  - W. H. Jackson (D)
- Seismic pulse studies
  - P. E. Byerly (D)
- Gravity map of the United States
  - H. R. Joesting (W)
- Geologic studies of active seismic areas
  - W. S. Twenhofel (D)
- Cross-country aeromagnetic profiles
  - E. R. King (W)
- Aeromagnetic profiles over the Atlantic Continental Shelf and Slope
  - E. R. King (W)
- Maine aeromagnetic surveys
  - J. W. Allingham (W)
- *Electromagnetic and geologic mapping in Island Falls quadrangle, Maine
  - F. C. Frischknecht (D)
- Gravity studies, northern Maine
  - M. F. Kane (W)
- *Geophysical and geologic mapping in the Stratton quadrangle, Maine
  - A. Griscom (W)
- Geophysical studies of Appalachian structure
  - E. R. King (W)
- Aeromagnetic studies, Concord-Denton area, North Carolina
  - R. W. Johnson, Jr. (Knoxville, Tenn.)
- Central and Western North Carolina regional aeromagnetic survey
  - R. W. Johnson, Jr. (Knoxville, Tenn.)
- Aeromagnetic studies, Middlesboro-Morristown area, Tennessee-Kentucky-Virginia
  - R. W. Johnson, Jr. (Knoxville, Tenn.)
- Aeromagnetic study of peridotite, Maynardville, Tennessee
  - R. W. Johnson, Jr. (Knoxville, Tenn.)
- Seismic survey for buried valleys in Ohio
  - R. M. Hazlewood (D)
- Geophysical studies in the Lake Superior region
  - G. D. Bath (M)
- *Texas coastal plain geophysical and geological studies
  - D. H. Eargle (Austin, Tex.)
- Gravity studies, Yellowstone area
  - H. L. Baldwin (D)
- Gravity profile of the southern Rocky Mountains, Colorado
  - D. J. Stuart (D)
- Gravity studies, Snake River Plain, Idaho
  - D. J. Stuart (D)
- Colorado Plateau regional geophysical studies
  - H. R. Joesting (W)
- Geophysical studies in the Rowe-Mora area, New Mexico
  - G. E. Andreasen (W)
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  - R. A. Black (D)
- Gravity studies, Sierra Valley, California
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- Gravity studies, southern Cascade Mountains, California
  - L. C. Pakiser (D)
- Pacific Northwest geophysical studies
  - W. E. Davis (W)
- Magnetic studies of Montana laccoliths
  - R. G. Henderson (W)
- Aeromagnetic and gravity studies of the Boulder batholith, Montana
  - W. E. Davis (M)
- Gravity and magnetic studies in western Montana
  - W. T. Kinoshita (M)
- Gravity survey of western Washington
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- Aeromagnetic and gravity studies in west-central Oregon
  - R. W. Bromery (W)
- Aeromagnetic surveys, Alaska
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- Regional gravity surveys, Alaska
  - D. F. Barnes (M)
- Geophysical studies in the Arctic Ocean
  - G. V. Keller (D)

Experimental geochemistry:
- Experimental geochemistry—hydrothermal silicate systems
  - D. B. Stewart, D. R. Wones, and H. R. Shaw (W), and J. Hemley and P. Hostetler (D)
- Experimental geochemistry—metallic sulfides and sulfosalt systems
  - B. J. Skinner, E. H. Roseboom, Jr., P. B. Barton, Jr., P. M. Bethke, and P. Toulmin, III (W)
- Hydrothermal solubility
  - G W. Morey (W)
- Chemical composition of thermal waters in Yellowstone Park
  - G. W. Morey (W)
- Solubilities of minerals in aqueous fluids
  - C. A. Kinzer and P. B. Barton, Jr. (W), and J. Hemley and P. Hostetter (D)
- Fluid inclusions in minerals
  - E. W. Roedder (W)
- Thermodynamic properties of minerals
  - R. A. Robie, B. J. Skinner, P. B. Bartin, Jr., P. M. Bethke, and P. Toulmin, III (W)
- Experimental geochemistry—alkali and alkaline earth salt systems
  - E-an Zen (W)
- Investigation of hydrothermal jasperoid
  - T. G. Lovering (D)
- Phase relations in rocks and experimental systems
  - F. Barker (W)
- Experimental studies on rock weathering and alteration
  - J. J. Hemley (D)
- Processes affecting solute composition and minor element distribution in lacustrine closed basins
  - B. F. Jones (q, W)

Mineralogy and crystal chemistry:
- Crystal chemistry
  - D. E. Appleman (W)
- Experimental mineralogy and crystal chemistry—rock-forming silicate minerals
  - D. E. Appleman (W)

Mineralogy and crystal chemistry—Continued
- Experimental mineralogy and crystal chemistry—phosphate minerals
  D. E. Appleman (W)
- Mineralogical studies and description of new minerals
  D. E. Appleman (W)
- Mineralogical studies and description of new minerals—micas and chlorites
  M. D. Foster (W)
- Mineralogical studies and description of new chromium-bearing minerals
  C. Milton (W)
- Mineralogical studies and description of new vanadium-bearing minerals
  A. D. Weeks (W)
- Crystal chemistry of borate minerals
  J. R. Clark and C. L. Christ (W)
- Crystal chemistry of phosphate minerals
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- Crystal chemistry of uranium minerals
  H. T. Evans (W)
- Sedimentary mineralogy
  J. C. Hathaway (D)
- Mineralogic services
  A. D. Weeks (W)
- Mineralogic services and research
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- Mineralogical services and research
  R. G. Coleman (M)
- Spatial distribution of chemical constituents in ground water, eastern United States
  W. Back (g, W)
- Geochemistry of ground water in the Englishtown formation
  P. R. Seaber (g. Trenton, N.J.)

Geochemical distribution of the elements:
- Geochemical distribution of elements
  M. Fleischer (W)
- Geochemical compilation of rock analyses
  M. Hooker (W)
- Minor elements in coal
  P. Zubovic (W)
- Dispersion pattern of minor elements related to igneous intrusions
  W. R. Griffitts (D)
- Geochemistry of minor elements
  E. S. Larsen, 3d (W)
- Uranium and thorium in magmatic differentiation
  E. S. Larsen, 3d (W)
- Chemical composition of sedimentary rocks
  H. A. Tourtelot (D)
- Mineral constituents in ground water
  J. H. Feth (g, M)
- Chemistry of hydrosolic metals in natural water
  J. D. Hem (q, D)
- Fluvial denudation in the United States. Phase 2.—Variance in water quality and environment
  F. H. Rainwater (q, W)
- Solute-solid relations in lacustrine closed basins of the alkali-carbonate type
  B. F. Jones (q, W)
- Occurence and distribution of strontium in natural water
  M. W. Skougstad (q, D)

Petrology:
- Origin and characteristics of thermal and mineral waters
  D. E. White (W)
- Igneous rocks of southeastern United States
  C. Milton (W)
- Studies of welded tuff
  R. L. Smith (W)
- Model studies of structures in sediments
  E. D. McKee (D)
- Porosity and density of sedimentary rocks
  G. E. Manger (W)
- Metamorphism and origin of mineral deposits, Gouverneur area, New York
  A. E. J. Engel (Pasadena, Calif.)
- *Petrology of the Manassa quadrangle, Virginia
  C. Milton (W)
- *Petrology of the Valles Mountains, New Mexico
  R. L. Smith (W)
- Petrology and geochemistry of the Laramide intrusives in the Colorado Front Range
  G. Phair (W)
- Petrology and geochemistry of the Boulder Creek batholith, Colorado Front Range
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- Ore deposition at Creede, Colorado
  E. W. Roedder (W)
- Magmatic differention in calc-alkaline intrusives, Mt. Princeton area, Colorado
  P. Toulman III (W)
- Wallrock alteration and its relation to thorium deposition in the Wet Mountains, Colorado
  G. Phair (W)
- Chemical and physical properties of the Pierre shale, Montana, North Dakota, South Dakota, Wyoming, and Nebraska
  H. A. Tourtelot (D)
- Lithologic studies, Colorado Plateau
  R. A. Cadigan (D)
- Mineralogy and geochemistry of the Green River formation, Wyoming
  C. Milton (W)
- Geology and paleolimnology of the Green River formation, Wyoming
  W. H. Bradley (W)
- *Petrology of the Bearpaw Mountains, Montana
  W. T. Pecora (W)
- Carbonatite deposits, Montana
  W. T. Pecora (W)
- *Petrology of the Wolf Creek area, Montana
  R. G. Schmidt (W)
- Petrology and chromite resources of the Stillwater ultramafic complex, Montana
  E. D. Jackson (M)
- Petrology of volcanic rocks, Snake River Valley, Idaho
  H. A. Powers (D)
- *Metamorphism of the Orofino area, Idaho
  A. Hietanen (M)
- *Geochemistry and metamorphism of the Belt Series; Clark Fork and Packsaddle Mountain quadrangles, Idaho and Montana
  J. E. Harrison (D)
- *Petrology of the Burney area, California
  G. A. Macdonald (Honolulu, Hawaii)

Petrology—Continued
- Glaucophane schist terranes within the Franciscan formation, California
  - R. G. Coleman (M)
- *Petrology and Volcanism, Katmai National Monument, Alaska
  - G. H. Curtis (M)
- Geological, geochemical, and geophysical studies of Hawaiian volcanology
  - J. P. Eaton (Hawaii)
- Hawaiian volcanoes, thermal and magnetic studies
  - J. H. Swartz (W)
- Petrological services and research
  - C. Milton (W)
- Sedimentary petrology laboratory
  - H. A. Tourtelot (D)

Organic geochemistry:
- Organic geochemistry and infrared analysis
  - I. A. Breger (W)
- Organic substances in water
  - W. L. Lamar (q, M)

Isotope and nuclear studies:
- Nuclear irradiation
  - C. M. Bunker (D)
- Geochronology: carbon-14 method
  - M. Rubin (W)
- Geochronology: K/A and Rb/Sr methods
  - H. Thomas (W)
- Geochronology: lead-alpha ages of rocks
  - T. W. Stern (W)
- Significance of lead-alpha age variation in batholiths of the Colorado Front Range
  - D. Gottfried (W)
- Geochronology: lead-uranium ages of mineral deposits
  - L. R. Stieff (W)
- Radiogenic daughter products
  - J. N. Rosholt (W)
- Isotope ratios in rocks and minerals
  - I. Friedman (W)
- Oxygen isotope geothermometry
  - H. L. James (M)
- Density comparison method for determining oxygen isotope ratios
  - J. H. McCarthy, Jr. (D)
- Isotope fractionation in living organisms
  - F. D. Sisler (W)
- Use of tritium in hydrologic studies
  - C. W. Carlston (g, W)
- Use of tritium in hydrologic studies
  - L. L. Thatcher (q, W)
- Occurence and distribution of radioelements in water
  - F. B. Barker (q, D)
- Tritium in ground water in the Roswell Basin
  - J. W. Hood (g, Albuquerque, N. Mex.)
- Tritium as a tracer in the Lake McMillan underground reservoir
  - H. O. Reeder (g, Albuquerque, N. Mex.)

Hydraulic and hydrologic studies:
- Textbook on ground-water geology
  - A. N. Sayre (w, W)
- Bibliography on hydrology and sedimentation
  - H. C. Riggs (s, W)

Hydraulic and hydrologic studies—Continued
- Sources of foreign papers (water)
  - V. M. Yevdjevich (s, W)
- Flow in smooth channels
  - H. J. Tracy (s, Atlanta, Ga.)
- Discharge characteristics of weirs and dams
  - C. E. Kindsvater (s, Atlanta, Ga.)
- Direct Measurement of boundary shear in open-channel flow
  - R. W. Carter (s, W)
- Variation in velocity-head coefficient
  - H. Hulsing (s, M)
- Depth-discharge relations in alluvial channels
  - D. R. Dawdy (s, W)
- Tidal-flow measurement
  - S. E. Rantz (s, M)
- Tidal-flow investigation
  - R. A. Baltzer (s, Lansing, Mich.)
- Wave-height piezometric registration
  - W. W. Emmett (s, Atlanta, Ga.)
- Effect of channel roughness (water)
  - H. J. Koloseus (s, Iowa City, Iowa)
- Directional permeability of marine sandstones
  - R. R. Bennett (g, W)
- Source of base flow of streams
  - F. A. Kilpatrick (s, Atlanta, Ga.)
- Effect of removing riparian vegetation, Cottonwood Wash, Arizona (water)
  - J. E. Bowie (s, Tucson, Ariz.)
- Water-loss and -gain studies in California
  - W. C. Peterson (s, M)
- California coastal basins hydrology
  - S. E. Rantz (s, M)
- Rainfall-runoff relations, Kentucky
  - J. A. McCabe (s, Louisville, Ky.)
- Cadwell Brook, Massachusetts (surface water)
  - G. K. Wood (s, Boston, Mass.)
- Hydrologic investigations, small watersheds, Trinity, Brazos, Colorado, and San Antonio River basins, Texas
  - W. H. Goines (s, Austin, Tex.)
- Hydrologic investigations, urban watershed, Austin, Texas
  - A. E. Hulme (s, Austin, Tex.)
- Effect of changes in forest cover on streamflow
  - F. M. Veatch (s, Tacoma, Wash.)
- General hydrology, West Virginia
  - W. L. Doll (s, Charleston, W. Va.)
- Hydrologic interpretation of topographic features
  - W. J. Schneider (s, W)
- Statistical techniques and appraisals
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- Roughness in alluvial channels and sediment transportation
  - D. B. Simons (q, Fort Collins, Colo.)
- Sediment transport parameters in sand bed streams
  - J. K. Culbertson (q, Albuquerque, N. Mex.)
- Factors affecting sediment transport—graphical representation of factors affecting bed-material discharge of sand bed streams
  - B. R. Colby (q, Lincoln, Nebr.)

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C. W. Lingham (s, Charlottesville, Va.)
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G. C. Goddard (s, Raleigh, N.C.)
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Geology and hydrology of Great Plains States as related to the management of radioactive materials
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- Geology and hydrology of the western states as related to the management of radioactive materials
  - R. W. Maclay (g, St. Paul, Minn.)
- Research on hydrology, National Reactor Testing Station, Idaho
  - E. H. Walker (g, Boise, Idaho)
- Hydrology of subsurface waste disposal, National Reactor Testing Station, Idaho
  - P. H. Jones (g, Boise, Idaho)
- Geology, hydrology, and waste disposal at the National Reactor Testing Station, Idaho
  - R. L. Nace (w, W)

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- Airborne radioactivity and environmental studies, Washington County, Maryland
  - R. M. Moxham (W)
- Nevada Test Site (ground water)
  - S. L. Schoff (g, D)
- Study of radioactive wastes
  - P. H. Carrigan (s, Chattanooga, Tenn.)
- Stream sanitation and water supply
  - G. C. Goddard (s, Raleigh, N.C.)
- Behavior of detergents and other pollutants in soil-water environments
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- *Geology in the vicinity of anthracite mine drainage projects, Pennsylvania
  - T. M. Kehn (Mt. Carmel, Pa.)
- *Flood control, Anthracite region, Pennsylvania
  - T. M. Kehn (Mt. Carmel, Pa.)

Geochemical and botanical exploration methods:
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  - F. C. Canney (D)
- Botanical exploration and research
  - H. L. Cannon (D)
- Geochemical halos of mineral deposits, California and Arizona
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- Geochemical prospecting techniques, Alaska
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  - R. S. Cannon, Jr. (D)
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  - B. J. Frederick (s, Chattanooga, Tenn.)
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  - E. G. Barron (s, Columbus, Ohio)
- Automation and processing techniques for water quality data
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  - R. E. Oltman (w, W)
- A study of methods used in measurement and analysis of sediment loads in streams
  - B. C. Colby (q, Minneapolis, Minn.)
- Electronic equipment development
  - J. E. Eddy (g, W)

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  - J. J. Fahey (W)
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  - L. C. Peck (D)
- Research on trace analysis methods
  - F. N. Ward (D)
- Trace analysis service and research
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  - W. W. Brannock (W)
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  - I. May (W)
- Analytical services and research
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  - W. D. Silvey (q, Sacramento, Calif.)
- Analytical methods—water chemistry
  - M. W. Skougstad (q, D)

Spectroscopy:
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  - I. Adler (W)
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  - A. W. Helz (W)
- Spectrographic services and research
  - A. T. Myers (D)
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  - H. Bastron (M)
- Spectographic methods of analysis
  - M. W. Skougstad (q, D)

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  - V. C. Kennedy (q, D)

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General bibliographies and handbooks:
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  - M. Cooper (W)
- Geophysical abstracts
  - J. W. Clarke (W)
- Geochemical exploration abstracts and information
  - E. L. Markward (D)
- Bibliography of tektites
  - B. L. Smysor (W)
- Treatise on ground-water mechanics
  - J. G. Ferris (g, W)

PUBLICATIONS IN FISCAL YEAR 1961

Listed below are citations of technical reports of the Geologic, Water Resources, and Conservation Divisions published or otherwise released to the public during the fiscal year 1961. The list also includes a few recent publications dated prior to July 1, 1960, that were not listed in Professional Paper 400–A. It does not include articles in a few periodicals dated prior to July 1, 1961, but released after this date.

The reports are listed alphabetically by author. In addition, an index to the reports is given on pages A–183 to A–194.

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