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Geology - Mineralogy
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UNITED STATES DEPARTMENT OF THE INTERIOR

GEOLOGICAL SURVEY

SEARCH FOR AND GEOLOGY OF RADIOACTIVE DEPOSITS

SEMIANNUAL PROGRESS REPORT

JUNE 1 TO NOVEMBER 30, 1952*

Classification changed from Confidential To Official Use Only
By authority of J. H. Eric, USGS Date 3/14/56

December 1952

Trace Elements Investigations Report 310

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USGS - TEI Report 310

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SEARCH FOR AND GEOLOGY OF RADIOACTIVE DEPOSITS

SEMIANNUAL PROGRESS REPORT

June 1 to November 30, 1952

SUMMARY

Uranium deposits in sandstones.--During the reporting period the stratigraphic studies program determined that the ore-bearing Shinarump conglomerate is essentially a discontinuous basal conglomerate of the Chinle formation and that distinctive lithologic units within the Chinle formation are traceable over broad areas of the Colorado Plateau. Pebble studies in the Shinarump conglomerate seem to show changes in the pebble composition, sphericity, roundness, and size that are probably due to paleogeologic controls such as distance from source areas.

Evidence gathered by ground-water studies of the Morrison formation tend to substantiate the ideas that (1) rocks favorable to ore deposits will readily transmit water and that (2) clusters of deposits in several widely separated areas are localized beneath a fluviatile conglomerate stratum at or near the base of the Brushy Basin member of the Morrison formation.

Geobotanical studies of indicator plants and correlation of their occurrence with drilling data have provided sufficient information for statistical analyses. The results of these analyses show that of the holes in the Yellow Cat area, 93 percent drilled in areas of indicator plants were in ground classed as favorable for ore on the basis of geologic criteria. Indicator plants were present near 81 percent of the drill holes containing ore, near 54 percent of holes containing mineralized rock of sub-ore grade and near only 12 percent of the unmineralized holes.

Geobotanical studies were also made to test the use of uranium absorber plants in prospecting the Jurassic Todilto limestone for uranium by sampling and assaying branches of pinyon (Pinus cembroides) and one-seed juniper (Juniperus monosperma). A content of 1.0 ppm uranium in the ash of the branch samples was used as indicative of mineralized ground. On this basis all known ore bodies or mineralized ground over which trees were sampled were confirmed by the tree branch analyses. Mineralized ground is now being found in the one area specifically drilled on tree branch anomalies.

The Cenozoic studies program has gathered evidence to show that several stages of orogenic deformation affected the ore-bearing formations of the Plateau during the early Tertiary; epeirogenic uplift began in Oligocene or early Miocene; and that several stages of orogenic deformation affected the Plateau in the late Tertiary and Quaternary.

Intrusions and volcanism on the Colorado Plateau seem to be late Tertiary in age and are much younger than the lead-uranium ages determined for the uranium deposits.

The mineralogic studies program continued to identify and describe minerals of the uranium deposits of the Colorado Plateau. Observation suggests that the rich black uranium ore occurs in environments protected from oxidation. Spectrographic analysis of drill-core samples have revealed a well-defined distribution pattern of metals normally associated with uranium ore adjacent to a dike of comminuted minette at Garnet Ridge, Apache County, Ariz. Reconnaissance study of the Ute Mountains showed that they contain about 30 major laccoliths radiating from two stocks; sulfides and ore deposits are found chiefly in one laccolith and not in the stocks.

Natural potential, electrical resistivity, and gravity surveys were made in selected areas in Monument Valley, Navajo and Apache Counties, Ariz. by the geophysical investigations program; all data of these studies have not yet been calculated but preliminary interpretation of resistivity measurements indicate that the trend and shape of channels at the base of the Shinarump may be traced. Electrical well-logging operations were carried out in selected mining areas in southwestern Colorado and southeastern Utah; preliminary results seem to indicate strong contrasts between unfavorable, favorable, and mineralized rock.

Detailed and reconnaissance geologic mapping and examination of anomalies detected by airborne methods in the Pumpkin Buttes area, Johnson and Campbell Counties, Wyo. show that the deposits are concentrated in a N-S belt about 30 miles long and 15 miles wide. All but the southern limit of this belt-shaped area has been established. Two types of deposits are present: (1) concretionary masses with iron and manganese, and (2) disseminated uranium minerals, which are more like the Colorado Plateau deposits than any found previously in the area. Lithologic guides to favorable ground developed during the field season are: reddish-gray to pink sandstone, presence of carbonaceous material associated with these sandstones, presence of manganese (applies only to type (1) deposits).

Uranium in veins, igneous rocks, and related deposits.--In conjunction with the project on the relation of uranium to post-Cretaceous vulcanism, surveys of glassy and crystalline post-Cretaceous rocks with a scintillation rate-meter show the crystalline rocks to be more variable in radioactivity; alteration of glassy rocks does not appreciably change the radioactivity indicating perhaps that uranium is deposited deeper than the near-surface solfataric zone.

Studies have shown that the concept of zoned relations of uranium deposits in metalliferous districts is suitable for indicating areas most favorable for uranium prospecting for the zoned complex base metal deposit (dominantly of mesothermal character) in the central part of the Colorado Front Range mineral belt.

In the Front Range, the zone of pyritic copper deposits, with or without appreciable gold, is generally unfavorable for pitchblende; and the zone of silver-lead-zinc deposits is either unfavorable or less favorable. But the zone of copper-zinc-lead deposits appears especially favorable--pitchblende is to be expected in the zone of overlap of copper with zinc and lead.

Field work in the Colorado Front Range disclosed abnormal radioactivity in one third of the mine dumps in the Freeland-Lamartine district, Clear Creek County; but only secondary uranium minerals were found. Favorable areas for uranium in this district are in a transition zone of silver-lead-zinc minerals. A pyritic-gold vein at the Golden Calf mine in the Dumont-Fall River area, Clear Creek County, contains generally high radioactivity and may be a possible source of uranium. In the Central City area, Gilpin County, recent discoveries of pitchblende have been made at the Old Town mine, the Spread Eagle mine and at a mine in Eureka Gulch. Uranium minerals were found on the dumps of five mines in northern Clear Creek County-- the Golden Calf, Martha E., Muscovite, Miller, and Ariadne. Mineralogic, geochemical and petrologic studies indicate that the association of thorium and uranium with bostonite previously noted in the Central City district is apparently also present in middle and northern parts of the Front Range mineral belt.

The fluorite deposits of the Thomas Range, Juab County, Utah are generally radioactive (ranging from 0.006 to 0.33 percent uranium); those in the southern part of the district are the highest but there is apparently a sharp decrease in grade with depth. In the Comet area, Jefferson County, Mont. moderate radioactivity anomalies were found at the Uncle Sam and Hattie Ferguson mines; sooty pitchblende was found in the dump of several mines along the Comet-Gray Eagle shear zone. There is a suggestion of a pattern formed by the areal distribution of the uranium deposition associated with the chalcedonic vein zones west and southwest of Clancey. If this pattern is true, there is a good possibility of additional uranium deposits north of Lump Gulch and a slight possibility of deposits east of Clancey. During field work in the Placerville area, San Miguel County, Colo. two new occurrences of radioactive material were discovered near the Weatherly property in the western part of the central Placerville area. At both localities, the radioactive material is hydrocarbon. The total inferred uranium reserves of these two occurrences is less than 2 tons of uranium-bearing rock that average 0.02 percent uranium.

The Shirley May (Garo), Colorado uranium deposit consists primarily of tyuyamunite and carnotite as disseminations and fracture fillings in three sandstone beds in the Maroon formation of Permian age. The ore body that has yielded most of the uranium ore is in the uppermost ore-bearing sandstone bed that is stratigraphically 50 and 150 feet above the other ore horizons. The uranium content of samples from the mine ranges from 0.001 to 0.48 percent uranium. Drilling in this area has given the following results: (1) A new sandstone bed was found that is a favorable host rock for uranium, vanadium, and copper ore bodies. (2) Potential uranium ore bodies occur in the sandstone beds within a vertical distance of 120 feet below the surface. (3) The area of known uranium mineralization is restricted to favorable parts of the sandstone beds within highly faulted areas. (4) Small uranium ore bodies possibly occur in the three sandstone beds within the area explored and to the northwest and southeast of the mine, but the cost of exploration and mining these bodies is not economical.

Uranium in carbonaceous rocks.--The reconnaissance search for western black shales indicates that extensive deposits of uraniferous black shale similar to the Chattanooga probably are not present. A revision of the method of approach to locating deposits of uraniferous black shales is under consideration. The approach would test, in more detail, shales of more favorable environment of deposition; shales that, by special processes could have acquired more uranium; and shales that show high radioactivity in the gamma logs made by oil companies.

Thin lenses of carbonaceous material, with an equivalent uranium content of approximately 0.1 percent, were found at Mulatto Canyon, Hosta Butte, and Marianna Pass, McKinley County, N. Mex. in the lower Gibson member of the Mesaverde formation. The caprock of Cuba Mesa, Sandoval County, N. Mex., shows radioactivity (about 0.012 percent equivalent uranium) highs which indicate the need of future prospecting in this area.

Marine black shales of the Pennsylvanian Hermosa formation near Durango, Colo. contain 0.002 to 0.004 percent uranium indicating the need for further investigation of this sequence. A 3-foot bed of lignitic shale north of Fort Collins, Larimer County, Colo. contains 0.006 percent uranium in the ash, thus indicating some need for investigations of the northern part of the Denver Basin where potential source beds overlie coals of the Laramie formation.

The area of uranium mineralization near Lusk, Niobrara County, Wyo. apparently extends 15 miles south into Goshen County. Samples from copper prospects in the pre-Cambrian Whalen group contain as much as 0.02 percent uranium. One lenticular bed of coal in the Cambria coal field near Newcastle, Weston County, contains 0.0085 percent uranium. Coke from lower coals in the same area contains 0.008 percent uranium.

Several beds of radioactive lignites were discovered in the Ekalaka lignite field, Carter County, Mont. The most highly uraniferous part of these beds contains as much as 0.14 percent uranium in the ash; much of the uraniferous lignite in the area contains about 0.01 percent uranium in the ash.

Search for possible source beds for uranium in the Jackson Hole, Wyo. area revealed a sequence of Pliocene rocks containing a total of about 660 feet of pumicite containing 0.001 percent uranium. Pliocene algal(?) limestones totalling 1100 feet in thickness in the Jackson Hole area contain up to 0.001 percent uranium, and may also have served as source beds for uranium deposits. Ground check of airborne radiometric anomalies in the Miller Hill area in south-central Wyoming found Miocene algal limestones which contain 0.01 to 0.15 percent uranium.

Analysis of mineralogical separates from coals of the Mendenhall Strip mine, Harding County, S. D. shows most of the uranium is associated with the organic components. Experiments on lignite columns indicate that the uranium is not displaced by base exchange and is probably held as an organo-uranium compound or complex.

Correlation of radioactivity with minor laminae, as part of coal petrographic studies on Dakota lignite, shows peaks of radioactivity associated with layers 1/2 inch or less in thickness. These peaks are obscured by the less refined methods of sampling. Indicated reserves in the Goose Creek district, Cassia County, Idaho, of strippable carbonaceous shale containing 0.005 percent or more uranium are 3,900,000 short tons (a total of 280 short tons of uranium). Core drilling in the Red Desert area, Sweetwater County, Wyo., indicates large deposits of uraniferous coal underlying Lost Creek flat (T. 23 and 24 N., R. 95 W.) and Battle Creek flat (T. 23 and 24 N., R. 94 W.). Estimated reserves found during the 1952 field season are about 176,700,000 short tons of strippable coal containing about 8,500 short tons of uranium. Reserves that were calculated from surface data compiled in 1951 from the Red Desert area are 513,800,000 tons of sub-bituminous coal, containing about 11,600 tons of uranium.

Investigations of the Chattanooga shale, in areas along the edge of the Nashville Basin, of inliers in southern Kentucky, and outcrop areas in Tennessee, northern Alabama and northwest Georgia make it seem unlikely that any area studied in 1952 will be of greater economic interest than the Block 1 area, DeKalb County, Tenn. Investigations of the organic material of the Chattanooga shale shows that in general much of the material is too fine to be identified, however, sporadic plant fossils indicate a marine ecology; remains of littoral plants and driftwood of land plants are also present.

<u>Uranium in phosphate</u>.--Developments in the northwest phosphate investigations include: clarification of critical stratigraphic correlation in the southwestern Wyoming part of the field and discovery at one locality, Basin Creek, of a 12½-foot bed of low grade phosphate at the top of the upper shale member, just below the Dinwoody contact. This bed was correlated over a fairly broad area but nowhere else was it as much as 3 feet thick.

Studies in the Florida land-pebble phosphate district, based on a limited number of samples, have shown that surface sands have a median range of 0.0047 inch in contrast with a range of 0.0018 inch for leached-zone samples. The contact between the surface sands and the leached-zone was picked when possible with the aid of gamma-ray logs; a sharp rise in radioactivity usually marks the contact.

Although the study of heavy minerals and insoluble residues of the stratigraphic units of the land-pebble district has only recently been initiated, study of a single mine face has revealed that: (1) phosphate appears to be more abundant in overburden sands than has previously been supposed; (2) garnet is virtually absent in surface sands, but appears to increase in abundance downward in the section; and (3) opaque minerals (probably including some black phosphate) increase from 1 or 2 percent in the heavy fraction of surface sands to about 60 percent in the heavy fraction of the underlying bed clay.

The logging and sampling of the drilling on the Royster tract, Polk County, Florida has been completed. A subsurface contour map of the top of the Hawthorn formation constructed from the data reveals: (1) A trough trending north-south which may have been part of a former river channel. (2) Numerous sink holes superimposed on the topographic highs and the troughs. (3) That the only relationship between the subsurface topography on the Hawthorn formation and present topography is in the eastern part of the tract, where a Hawthorn high closely parallels a prominent topographic ridge. Otherwise present topography is influenced by the Peace River drainage pattern.

Results of phosphate studies of the Survey's Eastern Gulf of Mexico project in the offshore area between Tarpon Springs and Fort Myers, Fla. show that phosphatic sediments are confined to a belt about 20 miles wide which extends from shore to a depth of 10 fathoms. The sediments in this zone are chiefly detrital and generally contain less than 0.50 percent P_2O_5. Within this zone are several smaller areas of sediment with a higher phosphate concentration (as much as 13.5 percent P_2O_5). The phosphate in these areas appears to have been derived, at least in part, from submarine outcrops of older formations.

Uranium in natural waters.--The streams draining uranium ore processing plants may be an economic source of uranium; one such river is the San Miguel in Colorado. This is the most promising possible source found during the 1952 field season. A sample collected from the river about 0.9 mile above the Vanadium Corp. of America's mill 12 miles from Uravan contained 1.0 ppb, and another taken 1.2 miles below the plant contained 55 ppb. The river, which has an average flow at Naturita of about 400 cfs, was in a flash flood at the time.

Another promising creek was Naturita Creek, in the eastern edge of the Uravan uranium-mining region. A sample from just below the forks of the creek about 4 miles northeast of Naturita contained 9.3 ppb. The normal flow of this stream is about 30 or 40 cfs.

Thorium and monazite deposits.--A belt of thorium and rare earth deposits six miles long has been found in the Mountain Pass district, San Bernardino County, Calif. The thorium content of the deposits in this district generally ranges between 0.02 and 0.5 percent ThO_2, with local concentrations as high as 5.5 percent ThO_2. In the Powderhorn district, Gunnison County, Colo., carbonate veins near Iron Hill contain 0.02 to 0.65 percent ThO_2; other new radioactive deposits were found in the area during the field season. In the Lemhi Pass district, Idaho-Montana, thorite is found in veins with quartz, barite, and hematite and in veins with quartz and copper sulfides. Reserves for the area, based on incomplete data, are in excess of 140,000 tons of quartz rock containing 0.8 percent ThO_2.

Regional reconnaissance in U. S.--In an investigation of the "Old Bed" apatite-rich magnetite deposit at Mineville, N. Y., tailings from the deposit were found to contain from 0.10 to 1.0 percent cerium, lanthanum, and yttrium, 0.004 percent uranium and probably about 0.03 percent thorium; these elements probably are in the apatite. About 1,300 tons of the "Old Bed" tailings are produced daily and several hundred thousand tons are in old tailing piles.

Investigations at the Mystery Sniffer claims in the Tushar Mountains, Beaver County, Utah have disclosed the presence of an essentially tabular body composed of highly altered rhyolite and latite containing pyrite, quartz, fluorite, and torbernite. The vein, or tabular body, strikes generally east, dips 35-70° N, and ranges in thickness from 10 to 65 feet. Preliminary estimates of inferred grade and tonnage of uranium-bearing material exposed to date by exploration work are 230,000 short tons containing 45 short tons (19 percent) of U_3O_8, of which 30,000 short tons contain 24 short tons (0.08 percent) of U_3O_8.

Regional reconnaissance in Alaska.--The so-called "Fowler carnotite prospect" has now been accurately located as lying on Nikolai Creek in the foothills of the southern Alaska Range, about 65 miles west of Anchorage. Original samples submitted by Fowler contain as much as about 0.6 percent uranium oxide. Natives who sampled the occurrence in 1949 indicate that carnotite occurs intermittently, if not continuously, over a distance of at least 6 miles along the base of an escarpment formed mainly by Tertiary coal-bearing rocks.

Analytical service and research on methods.--During the period, the laboratory completed 11,150 chemical determinations for uranium, 9,769 other chemical determinations; 128,958 spectrographic determinations and 18,469 radiometric determinations.

A successful method has been devised for the accurate determination of the phosphorus content of sea water. The method consists of simple separation in which the phosphorous in water is concentrated by copreсipitation of aluminum hydroxide. Arsenic, germanium, and silicon that may be carried down are removed by treating the precipitate with HF and HBr and volatilizing these elements. The phosphorous remaining is determined by the molybdenum blue procedure under optimum conditions previously established.

Geochemical and petrological research on basic principles.--As part of the investigation of distribution of uranium in igneous complexes, chemical determinations on about 35 granitic rocks ranging from granite to gabbro, carefully selected to represent the Southern California batholith, have been plotted on a variation diagram. The uranium determinations so plotted do not make so smooth a curve as do the major constituents. The gabbros have a strong tendency to be low in uranium (about 0.2 ppm) and the granites to be high in uranium (5.0 ppm). The estimated average uranium content of the batholith is 2.5 ppm.

Four significant facts have been shown about the Colorado Plateau uranium deposits from the isotope geology studies: (1) The ages of the best specimens of ore from the Morrison and Shinarump conglomerates are appreciably less than the ages of the sediments which enclosed them. (2) The ages which have been found for these ores from the Morrison formation and the Shinarump conglomerate are essentially the same. This strongly suggests that the deposits were actually formed at the same time regardless of the age of the enclosing sediments. More important, this means that the origin of the Colorado Plateau ores cannot be determined successfully if the problem is subdivided into the problem of the Morrison ores, the origin of the Morrison ores, the origin of the Shinarump ores, etc. (3) The age of the uranium ore in the vein deposits in Placerville area—ore that is quite similar in many respects to the ores in the Temple Mountain district—is also approximately the same as the age of the Shinarump and Morrison ores. (4) The age of the uraninites from the Colorado Front Range is essentially the same as the age which has been found for the Morrison and Shinarump deposits. This would suggest a single period of mineralization for both the Colorado Front Range and the Colorado Plateau.

Mineralogic and petrographic service and research.--The crystal structure of montroseite has been determined by H. T. Evans; preliminary structural studies have been made on "lumsdenite", a new vanadium oxide; these structural studies have made possible the determination of the chemical formulas of these minerals.

Geophysical prospecting services and research on methods.--Portable gamma-ray logging units for small diameter holes have been developed, utilizing both Geiger counters and scintillation counters as the detector element.

Airborne radioactivity surveying disclosed two new areas in which uranium was not previously known - the Miller Hill area in southwest Carbon County, Wyo., and the Devils Tower area in Crook County, Wyo. Preliminary field investigation of the 10 radiometric anomalies in the 90-square-mile Miller Hill area showed that some of the anomalies were due to uranium-bearing limestone of Miocene age. Five radioactive anomalies were recorded in Crook County, Wyo.

SEARCH FOR AND APPRAISAL OF URANIUM IN SANDSTONE-TYPE DEPOSITS

Colorado Plateau geologic studies

Introduction
by L. C. Craig and G. W. Weir

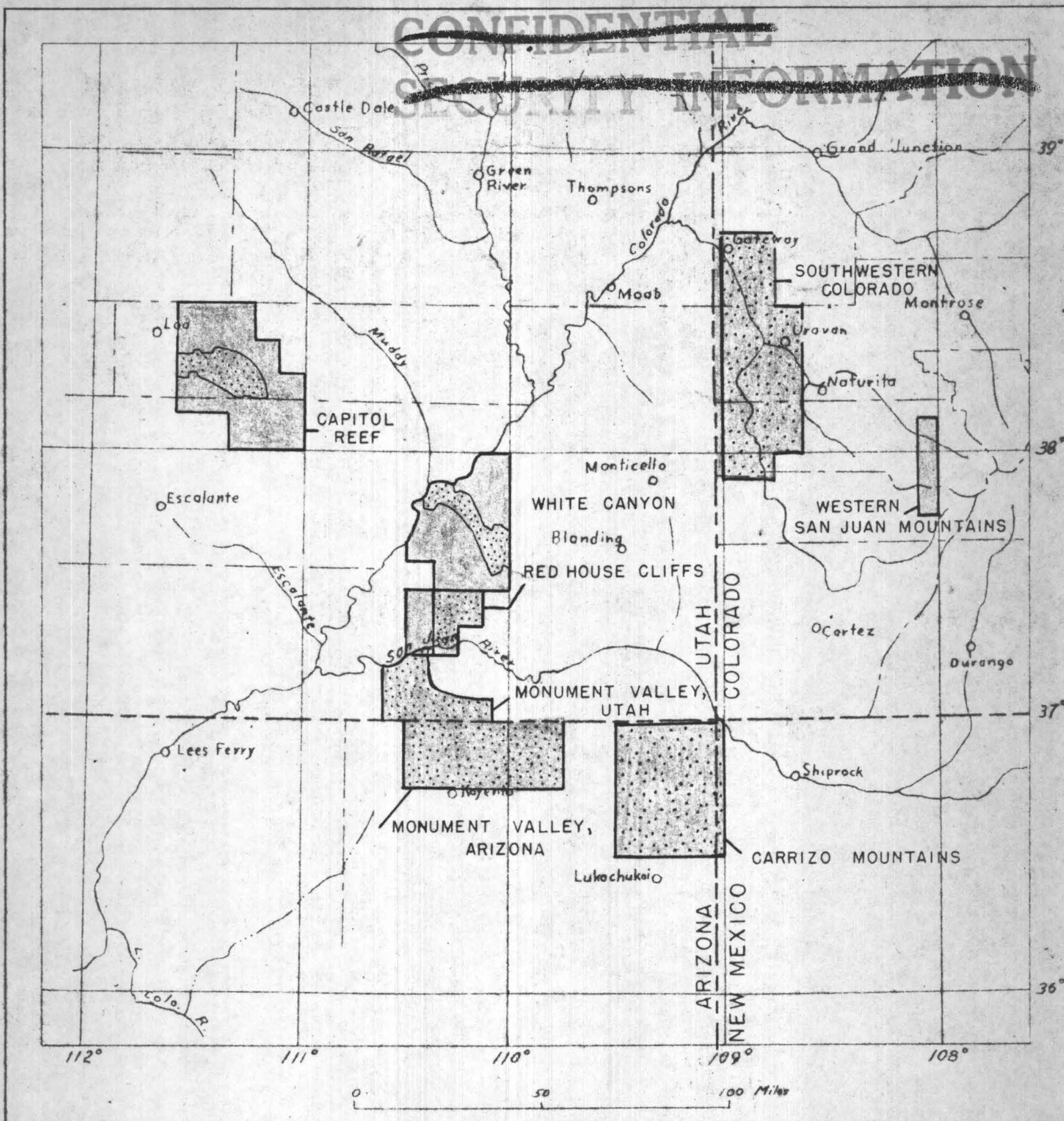
The Colorado Plateau geologic studies comprise a number of geologic mapping and specialized geologic studies of the pre-Morrison (mainly Triassic) and Morrison uranium-bearing formations. The principal objectives are to determine the distribution and character of the uranium deposits and the distribution and character of areas favorable to mineralized rock; to determine, either from knowledge of mineral habit or mineral origin, geologic relations that may be useful in ore-finding, and to appraise the uranium resources of the Colorado Plateau region.

Beginning with this report, all the Colorado Plateau geologic studies have been placed on a semiannual reporting basis. Rapid reporting of findings of special significance will be assured by reporting such discoveries either in the Trace Elements monthly reports or in separate reports.

Geologic mapping

Southwestern Colorado project, by F. W. Cater, Jr.

The principal objectives of the regional geologic mapping project in southwestern Colorado (fig. 1) are to determine the geographic and geologic distribution of the carnotite deposits, the broad geologic controls, and the relations to regional stratigraphy and structure, as well as to delimit areas favorable for detailed studies and exploration.



EXPLANATION

Area to be mapped

Mapping completed, November 30, 1952

Figure 1.-- INDEX MAP OF PART OF THE COLORADO PLATEAU SHOWING LOCATION OF MAPPING PROJECTS

Compilation of geologic maps and preparation of reports for publication in the Geological Survey Quadrangle Map Series were resumed September 15, 1952. The status of the various phases of this work on the eighteen $7\frac{1}{2}$-minute quadrangles in southwestern Colorado is shown below:

Compilation of topographic base maps from air photos. . . .	100%
Preparation of structure contour maps	100%
Preparation of structural sections.	100%
Writing of texts to accompany geologic quadrangle maps. . .	50%
Editorial review and criticism.	20%

In addition, preparation of a paper for publication on the structural development of salt anticlines on the Colorado Plateau was 75% completed. It is anticipated that the project will terminate with the completion of these map reports by June 1953.

<u>Carrizo Mountains project</u>, by J. D. Strobell, Jr.

Geologic mapping of the Carrizo Mountains area, Apache County, Ariz., and San Juan County, N. Mex., (fig. 1) was undertaken to provide detailed information on the geologic setting of carnotite deposits in the 30-minute quadrangle surrounding the Carrizo Mountains. All known deposits in the area occur in the Salt Wash member of the Morrison formation. The geologic mapping of this 1,000 square mile area was completed September 1, 1952, except for the laccolithic complex of the Carrizo Mountains. Preliminary copies of this geologic map at 1:20,000 scale were transmitted to the Atomic Energy Commission as TEM reports 415-430 in June, July, and August 1952.

A geologic map of the part of the area completed, a brief text, and stratigraphic sections are being prepared for transmittal to the Fuels Branch of the Geological Survey for publication at 1:48,000 scale in the Oil and Gas Investigation Map series.

A preliminary appraisal of the uranium resources of the Carrizo Mountains area was transmitted to the Atomic Energy Commission as TEM-300 in June 1952.

The project will be recessed from December 1952 until about May 1953. At that time mapping of the igneous-sedimentary complex of the Carrizo Mountains laccoliths will be undertaken to determine the relations of the ore deposits to igneous activity in the area.

San Juan Mountains project, by A. L. Bush

The vanadium deposits in the Entrada sandstone in the western San Juan Mountains, Colo., contain a small but significant amount of uranium. These deposits are in the Placerville district, San Miguel County; the Barlow Creek-Hermosa Creek district, Dolores and San Juan Counties; and the Lightner Creek district, La Plata County. In June 1952 the Geological Survey began a program of detailed study of the districts in order to obtain an appraisal of the uranium-vanadium resources, to recommend areas favorable for exploration, to determine geologic guides to ore, and to gain information about the origin and geologic controls of the ore deposits.

During the field season of 1952 reconnaissance of outcrops of the Entrada sandstone was made, mines and critical areas were mapped and sampled, and production and assay records and available geologic data were compiled. TEM-298, "Preliminary report on the uranium and vanadium resources of the Entrada sandstone, western San Juan Mountains, Colorado," by A. L. Bush and Leonid Bryner is being prepared for transmittal to the Atomic Energy Commission. This appraisal was summarized in Trace Elements monthly report, October 1952. A more detailed report will be prepared after receipt of analyses, study of production records, and petrographic examination of specimens of ore and host rocks. Detailed geologic mapping of three $7\frac{1}{2}$-minute quadrangles (fig. 1) near Placerville, Colo., will begin in the field season of 1953 and will probably lead to some deep drilling to test for extensions of the Placerville and Barlow Creek-Hermosa Creek mineral belts.

<u>Monument Valley, Arizona project</u>, by I. J. Witkind

Objectives of the Monument Valley quadrangle mapping project, Apache and Navajo Counties, Ariz., (fig. 1) are to appraise the uranium resources of the area, to determine geologic guides for prospecting, to locate areas favorable for exploration by drilling, and to map and study the uranium-bearing and adjacent strata to determine regional controls and habits of the uranium deposits.

Geologic mapping and field studies were undertaken during the field seasons of 1951 and 1952. Three 15-minute quadrangles were mapped. These comprise an area of about 700 square miles on the Navajo Indian Reservation in northeastern Arizona. The mapped area is bounded by parallels of latitude $36^{\circ}45'$ and $37^{\circ}00'$ and meridians of longitude $109^{\circ}45'$ and $110^{\circ}30'$.

Consolidated sedimentary rocks having an aggregate thickness of over 5,000 feet and ranging in age from Permian to Jurassic crop out in the area. Dikes and plugs of minette and tuff breccia are intruded into the sedimentary strata.

The major structural feature in the area is the Monument upwarp, a broad flattened anticline with a north-south axis. Structure contours indicate that subordinate structural elements are superimposed on this major feature.

Uranium-vanadium ore occurs in channel sediments of the Shinarump conglomerate. Most ore deposits are of the "carnotite" type and the major ore bodies are erratically distributed along a channel's length.

The predominant ore mineral is either carnotite (?), tyuyaminite (?), or locally, an unnamed uranyl vanadate. Many ore deposits have copper minerals, such as azurite, malachite, chalcocite, and chalcopyrite, intimately associated with the uranium minerals.

The workings of the largest mine in the area, the Vanadium Corporation of America's Monument No. 2 mine, were mapped during the 1952 field season. Major ore bodies in the mine are in the form of ovate cylindrical bodies, known as rolls, and are concentrated locally in conglomeratic sandstone lenses along the channel's length. Preliminary work suggests that the rolls formed in two ways. The first appears to be by "replacement" of wood by silts, limonite, and carnotite (?). The second appears to result from an impregnation of sandstone by limonite and carnotite (?).

The geologic features believed to be of greatest usefulness as guides in the search for new ore deposits in the Monument Valley area are channels, organic matter, and conglomerate containing organic matter; of less or uncertain value as guides are limonite impregnation, copper minerals, a bleached zone at the top of the Moenkopi formation, and clay boulders, cobbles, and pebbles. As shown particularly by the Monument No. 2 mine, the ore is commonly in zones along the length of channels; these zones are separated by barren ground. That channels are barren at the outcrop does not necessarily mean that they are barren along their entire lengths. The common occurrence in the Monument Valley area, Ariz., of geologic features useful as guides to ore deposits indicates that the area is favorable for the discovery of new ore deposits.

The Mitchell Butte Mesa area, Navajo County, Ariz., contains in basal channel sediments an exposed seam of carnotite about 4 feet wide and about 1/4 inch thick. The channel strikes N. 55° W., is about 350 feet wide and has been cut about 75 feet in the Moenkopi. Recommendations of the area for exploration by diamond drilling are being considered, but accessibility to the top of the mesa is difficult and road construction costs would be high. Other parts of Monument Valley, Ariz., that appear favorable are being investigated presently by drilling programs of the Atomic Energy Commission or await the results of current geophysical investigations by the Geological Survey before receiving consideration for drilling recommendations.

Preliminary geophysical results suggest that under favorable conditions electrical resisitivity methods can delineate the trend of channels and it is recommended that drilling programs be preceded by geophysical studies. This should permit planning of exploration programs that would provide thorough tests along the lengths of channels.

Field work in the assigned program has been completed. Plans for the next six month period include (1) completion of TEM-536 (in preparation), a preliminary report on the results of this project, (2) preparation of a detailed final report on the Monument Valley area for transmittal to the Atomic Energy Commission, and (3) preparation of a report presenting the results of mapping at the Monument No. 2 mine. In addition a formal U. S. Geological Survey publication on the geology of the area will be prepared.

[illegible] structures in the deposit and [illegible] that this area [illegible] the [illegible] deposits.

[illegible] Area [illegible] County [illegible] and [illegible] area [illegible] about 150 [illegible]. Recommendations of the [illegible] the [illegible].

[illegible] that [illegible] Atomic Energy Commission [illegible] recommendations.

[illegible] under Federal [illegible] and designate the [illegible] recommended that [illegible] the land [illegible] be [illegible].

[illegible] has been completed. Plans for the [illegible] preparation of a report presenting the [illegible] of this area will be prepared.

vanadate (carnotite? or tyuyamunite?).

Copper minerals, mostly carbonates and sulfates, are commonly associated with the uranium minerals, but copper minerals are also found at many places where uranium minerals are absent. Sulfide copper minerals are rare but small amounts of chalcocite, bornite, chalcopyrite, and covellite were found.

Within the channel sediments of the Shinarump, the uranium minerals appear to be associated with zones of relatively high permeability. These zones are marked by the presence of conglomerate, clay galls, friable sandstone, fractional clay lenses, or open-textured woody remains.

The associations of uranium minerals with channels, with copper minerals, and with relatively permeable zones are regarded as the best geologic guides for use in prospecting for uranium in the area. Results of this geologic study, as well as the results of tests by mining or by diamond drilling, indicate that the Monument Valley, Utah, area occupies a less important position than most other uranium mining districts in the Colorado Plateau that produce from the Shinarump. Small tonnages of uranium ore may be mined from several mineralized localities in the area, and even this small production may be severely limited by the condition of access roads or by other economic factors.

No large scale exploration programs for the Monument Valley, Utah area can be recommended at this time. Small drilling projects in readily accessible ground behind known mineralized exposures might be warranted but the risks are high and such drilling probably is not feasible at present.

Field work for the Monument Valley, Utah, project has been completed. A preliminary report on geologic investigations in Monument Valley, Utah, is in preparation. Plans include petrographic studies and map compilation leading to the completion of a comprehensive TEI report to be transmitted in the spring of 1953.

Red House Cliffs project, by T. E. Mullens

The purpose of the Red House Cliffs quadrangle mapping project is to appraise the uranium resources of the Red House Cliffs area by mapping and studying rocks exposed in the area with particular emphasis on the uranium-bearing Shinarump conglomerate.

The Red House Cliffs area is located in southwestern San Juan County, Utah (fig. 1). The area includes the following 7½-minute quadrangles: Clay Hills 2 NE, 2 SE, 2 SW, and 1 NW in the Clay Hills 30-minute quadrangle. These quadrangles contain the area of Triassic rock exposures on the western flank of the Monument upwarp between the head of Red Canyon and the San Juan River.

Field work in the Red House Cliffs area started July 6, 1952, and continued until October 1, 1952. During the field season the Chinle-Moenkopi contact in three 7½-minute quadrangles, about 20 miles of outcrop, was studied in detail and examined for uranium minerals. These quadrangles are Clay Hills 1 NW, 2 NE, and 2 SE. Geologic mapping of the three quadrangles was about 90 percent completed during the field season. TEM-537, "Preliminary report on geologic studies in the Red House Cliffs area, San Juan County, Utah," by T. E. Mullens and H. A. Hubbard, is being prepared for transmittal to the Atomic Energy Commission. It summarizes the results of the field studies.

No known deposit of uranium minerals occurs in the part of the Red House Cliffs area mapped in 1952.

The probability of finding uranium ore in the three quadrangles mapped in 1952 is low because there are few beds favorable for these deposits. Only five lenses of Shinarump conglomerate are present in the area mapped in 1952. The largest lens extends about 2 miles along outcrop and has a maximum thickness of 20 feet. The other four lenses are each less than a quarter of a mile in outcrop length and less than 8 feet wide. Malachite, a copper carbonate, is disseminated in one of the smaller lenses, but no radioactive material is associated with the malachite.

The other formations exposed in the mapped area were also examined for uranium minerals. All these formations were barren of uranium and copper minerals and the probability of finding uranium ore deposits in these formation is thought to be low.

Shinarump conglomerate is well-developed in the part of Red House Cliffs area not yet mapped. This Shinarump was not studied or mapped in detail, but because it is relatively thick and continuous, it is judged to be more favorable for ore deposits than the Shinarump found in the area already mapped.

Geologic mapping and studies in the Red House Cliffs area have resulted in correlation of a cliff-forming unit at the top of the Cutler formation with the Hoskinnini tongue of the Cutler formation of Monument Valley.

Geologic mapping in the area has revealed two faults zones which may be related to localization of uranium ore north of the Red House Cliffs area. These two fault zones extend beyond the north boundary of the Red House Cliffs area and into Red Canyon where they crop out near some of the uranium mines. No uranium minerals are associated with the fault zone in the Red House Cliffs area, and more field work is needed to prove or disprove any relation between these faults and the uranium deposits in Red Canyon.

It is possible that in addition to the four quadrangles already assigned to the project, the 7½-minute quadrangle Clay Hills 2 NW, bounded by 37°22'30" and 37°30' north latitude and 110°22'30" and 110°30' west longitude, may also be mapped. This quadrangle is bounded on the east and south by quadrangles assigned to the project, and mapping of it would complete the structural pattern of the Red House Cliffs area and would test the possible relation between structural pattern and localization of uranium ore.

Mapping of the Clay Hills 2 NW quadrangle would take about four weeks and would be done most economically in the summer of 1953. The Red House Cliffs field party will be in the general area of this quadrangle during most of the field season of 1953 in connection with work already assigned.

Plans for the Red House Cliffs project are to prepare an interim report during the winter of 1952-53, to complete mapping and geologic studies in the area during the summer of 1953, and to complete a final report on the project by January 1954.

White Canyon project, by A. F. Trites, Jr.

The objectives of the White Canyon project are to appraise the uranium resources of the area, to determine controls and guides to ore and suitable areas for physical exploration, and to map and study the ore-bearing and adjacent strata to determine habits, character, and regional geologic controls of the uranium deposits.

The White Canyon area is on the west flank of the Monument upwarp in the central part of San Juan County, Utah, approximately 50 miles west of Blanding, Utah.

During the period of this report, field mapping was carried on from May 31 to October 28, 1952. Approximately 50 square miles in the lower part of White Canyon were mapped by plane table and telescopic alidade. About 20 square miles were mapped on aerial photographs, and 12 linear miles of Shinarump horizon were examined in detail. Detailed examinations were made of the Happy Jack mine and the Tiger (Hideout) and White Canyon No. 1 claims.

The White Canyon area contains exposures of sedimentary rocks, ranging in age from Pennsylvanian to Jurassic.

Three types of uranium deposits are recognized on the basis of the grain size of the enclosing Shinarump beds: (1) sandstone, (2) conglomerate, and (3) siltstone or very fine-grained sandstone deposits. The largest, highest grade, and most continuous ore bodies are found in coarse- to very coarse-grained sandstone. Most of the ore from the Happy Jack Mine and the Tiger (Hideout) claim has come from sandstone. The uranium deposits in conglomerate are confined to channels and contain high-grade areas separated by rock of sub-ore grade. Workings at the White Canyon No. 1 mine have recently been opened on a deposit in a bed of conglomerate in the Shinarump. Uranium deposits in very fine-grained sandstone or siltstone are known in only a few places. Parts of the Happy Jack mine contain deposits of this kind.

Pitchblende or uraninite, previously known to occur at the Happy Jack and Posey mines, and the Tiger (Hideout) claim has recently been tentatively identified at the Markey and White Canyon No. 1 claims. Secondary uranium minerals, including sulfates, silicates, phosphates, and carbonates, have been found in many deposits. The uranium minerals occur principally (1) in clay stringers, (2) adjacent to changes in lithology, (3) as replacements of wood, and (4) as impregnations in sandstone and conglomerate.

Geologic data from White Canyon indicates that the area is favorable for the discovery of new uranium deposits. The Atomic Energy Commission is exploring favorable ground near the Happy Jack mine and on Frey Point. TEM-479, "Preliminary report on the geology at the Tiger (Hideout) claim, White Canyon area, San Juan County, Utah, with recommendations for exploration for geologic information," by T. L. Finnell, B. L. Renzetti, and A. F. Trites, Jr. was submitted to the Atomic Energy Commission in August 1952. Exploration recommendations made in this report are being reconsidered in the light of additional geologic information.

Plans for the project for the remainder of 1952 and early 1953 include (1) petrologic study of the sedimentary rocks of White Canyon area, (2) mineralogical study of specimens from the Happy Jack mine and the Tiger (Hideout) and White Canyon No. 1 claims, and (3) preparation of maps and reports on the White Canyon area and the mines examined. TEM-540, "Preliminary report on geologic investigations in White Canyon, San Juan County, Utah, 1952," by A. F. Trites, Jr. and T. L. Finnell is being prepared for transmittal to the Atomic Energy Commission. Among the reports now in preparation are

TEI-240, "Uranium and copper deposits at the Gonway and North Point Claims, White Canyon area, San Juan County, Utah," by A. F. Trites, Jr. and E. P. Beroni; and a detailed interim report on the geology of the White Canyon area by A. F. Trites, Jr. et al. Regional mapping and field study of the uranium deposits will be resumed in the spring of 1953.

<u>Capitol Reef project</u>, by J. Fred Smith, Jr.

Objectives of geologic studies and quadrangle mapping in the Capitol Reef area, Wayne and Garfield Counties, Utah, (fig. 1) are to appraise the uranium resources of the area, to determine geologic guides for prospecting, to locate areas favorable for exploration, and to map and study the uranium-bearing Shinarump conglomerate and adjacent strata to determine the regional controls and habits of the uranium deposits.

The area in which mapping has been completed is in western Wayne County, Utah. The complete area to be mapped includes a part of northern Garfield County and has irregular boundaries between $38^{\circ}00'$ and $38^{\circ}30'$ N. Lat. and $111^{\circ}07'30''$ and $111^{\circ}37'30''$ W. Long.

Consolidated sedimentary rocks exposed range in age from the Permian (Coconino sandstone) to Jurassic Morrison formation and have an aggregate thickness of more than 5,000 feet. Volcanic rocks occur in the western part of the area. Structural features include the Teasdale anticline and numerous normal faults.

Most radioactive rock in the area is in a claystone layer at the base of Triassic Shinarump conglomerate beds that have filled channels cut into the underlying Moenkopi formation. The claystone layer in the channels contains much carbonaceous material and some stringers of sandstone and siltstone. At the Floral Reef claims Shinarump sandstone along and near three vertical fractures is more than normally radioactive and is heavily stained with iron and manganese.

Metatorbernite and zippeite have been found in the Oyler mine, and light green radioactive minerals, tentatively identified as torbernite or metatorbernite, have been found at the Birch Spring and Floral Reef claims. Secondary copper minerals (probably copper sulfates) are associated with the uranium minerals, but copper staining is much more widespread than uranium minerals. Disseminated chalcopyrite and secondary copper minerals with no associated radioactive rock are found locally in limestone in the lower member of the Moenkopi formation.

Radioactive asphaltite forms coatings on and blebs in the Shinarump in sec. 36, T. 29 S., 26 E. Non-radioactive asphaltite and petroliferous rocks have been noted in the Kaibab limestone and the Moenkopi formation.

The habits of uranium occurrence in the Capitol Reef area indicate that the following geologic features may be useful as guides for prospecting, particularly where several are found together:

1. Shinarump sediments in channels cut into the underlying Moenkopi formation.
2. Copper minerals.
3. Fractures heavily stained with iron and manganese.
4. Concentration of carbonaceous matter.
5. Clay layer at base of Shinarump conglomerate.
6. Thick zone of bleached clay and siltstone at the top of the Moenkopi formation.
7. Asphaltite.

Areas favorable for uranium deposits are limited to the Shinarump conglomerate. There are no producing uranium mines in the Capitol Reef area, but several localities with above normal radioactivity are being prospected by private parties. At present, no parts of the area studied are considered favorable for drilling exploration.

TEM-538, a preliminary report on geologic studies in the Capitol Reef area, is in preparation. During the next six-month period, rocks and minerals will be examined in thin section, by sedimentary analysis, and by chemical and mineralogical analysis, and an interim report will be prepared. Geologic mapping, including examination of more Shinarump conglomerate, will be resumed in the spring of 1953.

Photogeologic mapping
by W. A. Fischer

The photogeologic mapping program is designed to provide regional geologic maps of specified areas in Utah, Colorado, Arizona, and New Mexico to serve the needs of the Atomic Energy Commission and the Geological Survey until more detailed ground surveys can be made.

Since the beginning of the photogeology project in the winter of 1951-52, approximately 7,000 square miles of geologic mapping has been completed or is in the latter stages of production. These areas completed or in active production are shown on figure 2.

As a result of conferences held in August 1952 with Larry Craig and Fred Smith of the U. S. Geological Survey, the amount of detail presented on the photogeology maps has been increased.

The areas now scheduled for production are shown on figure 3.

FIGURE 2

INDEX MAP
SHOWING PROGRESS OF PHOTOGEOLOGIC MAPPING IN
THE COLORADO PLATEAU AREA

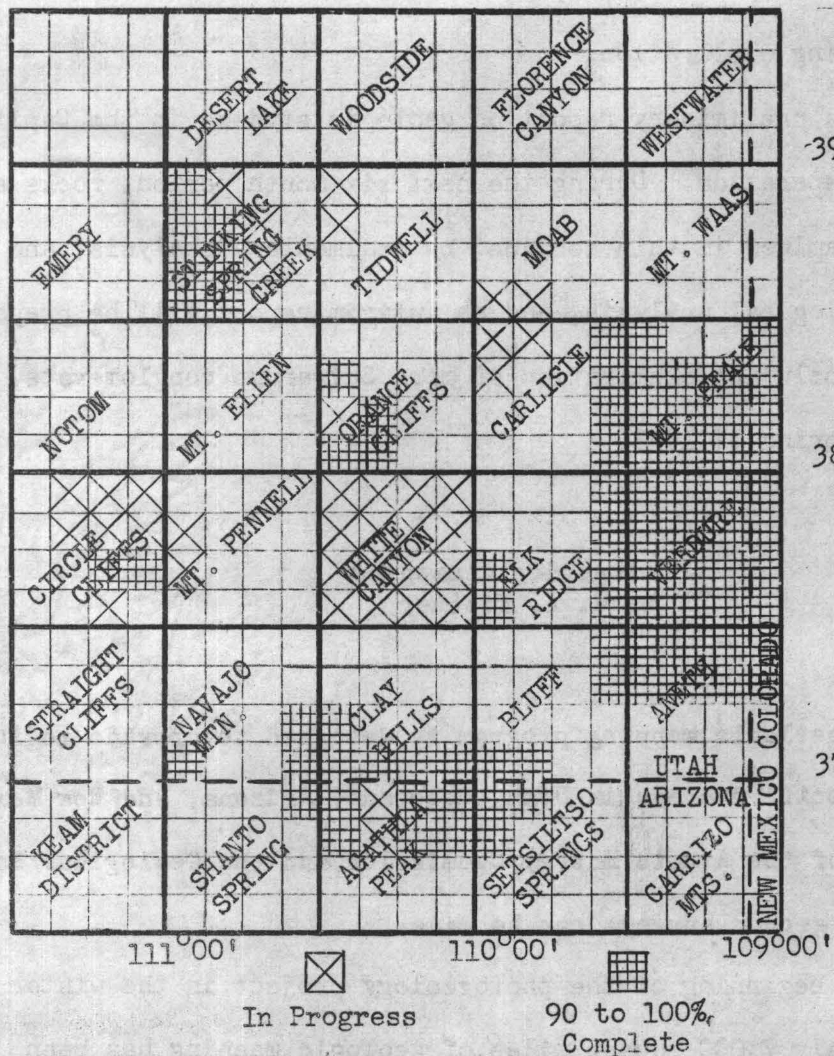
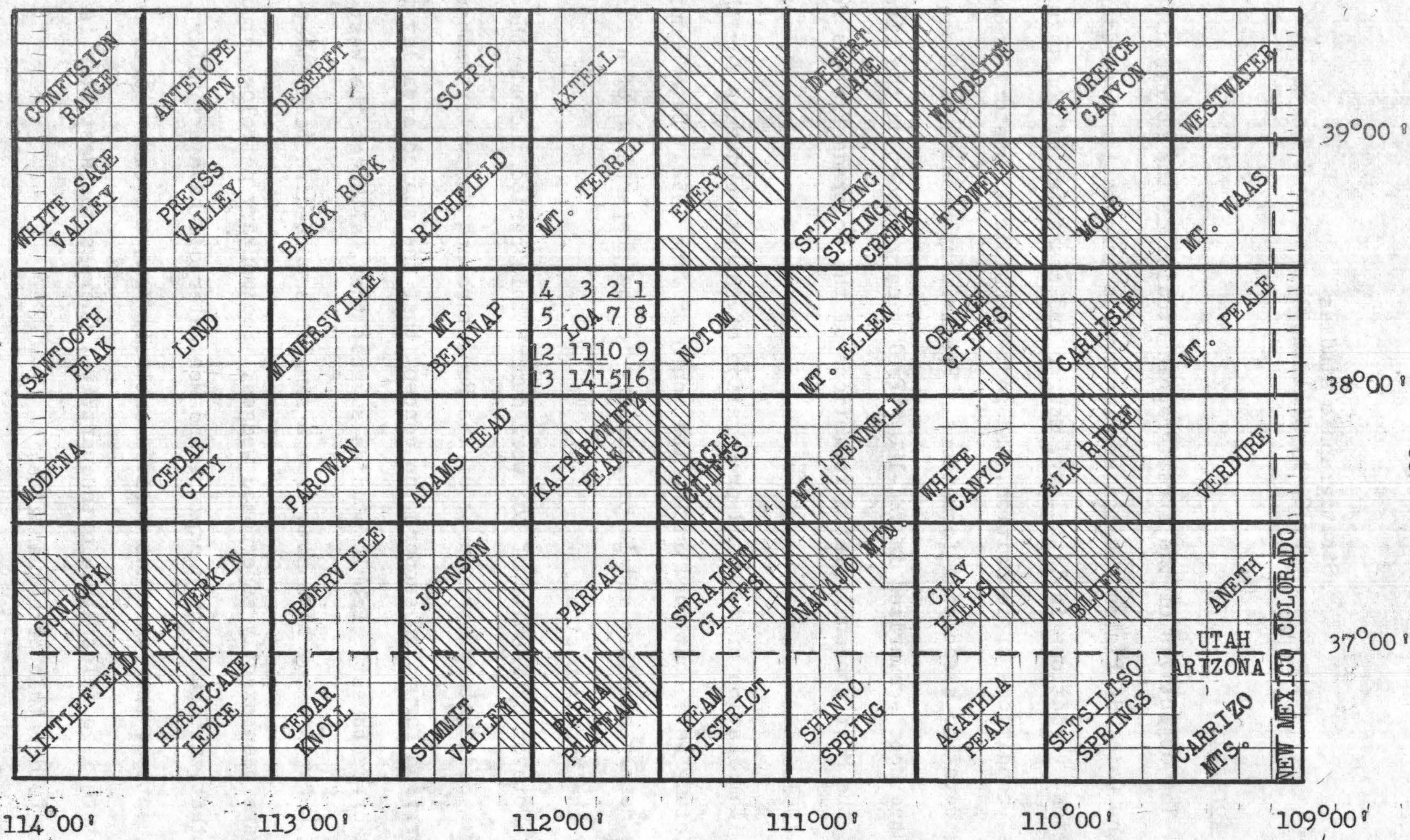


FIGURE 3

INDEX MAP

Showing scheduled photogeologic mapping for fiscal 1953-55



30' quadrangles subdivided into 16 $7\frac{1}{2}$ quadrangles (see Loa quadrangle)

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Stratigraphic studies
by G. A. Williams

Morrison formation

The objectives of the stratigraphic studies of the Morrison formation of the Colorado Plateau region are to provide information regarding distribution, variations in lithology, source and character of constituting materials, conditions of deposition, and post-depositional history of ore-bearing strata and associated formations. Preliminary results of these studies have been summarized in TEI-180, "Preliminary report on the stratigraphy of the Morrison and related formations of the Colorado Plateau region," November 1951.

Compilation of data and preparation of reports and maps for the Morrison study were continued during the month of June 1952. Data compilation is nearly complete and is preliminary to the preparation of a final report of the Morrison study.

Noteworthy results of the work during this period include the following: Sedimentary structures of the Recapture and Westwater members of the Morrison formation support the concept that the source area lay to the south or southwest. Pebble studies suggest that, although the Westwater and Recapture may have come from a similar source-direction, they may not have been exactly superposed wedges. Sedimentary petrology studies indicate that, although the Recapture and Westwater did have a similar source-direction, they were not derived entirely from the same source rocks. The Recapture is a feldspathic orthoquartzite, whereas the Westwater is an arkose and feldspathic orthoquartzite.

The Morrison study was recessed July 1 until November 30 except for special studies conducted by the sedimentology laboratory for the purpose of training personnel in new techniques. Pebble studies were made in two Salt Wash localities, not previously reported, in the Capitol Reef area.

Plans for the next six months call for the completion of the sedimentology and sedimentary structure parts of the final report on the Morrison study. Laboratory studies of the Morrison pebbles will be completed and a contribution to the final report prepared. TEI-180, "Preliminary report of the stratigraphy of the Morrison and related formations of the Colorado Plateau," by L. C. Craig, et al. is in the final stage of editing prior to publication as a formal Geological Survey report.

Triassic formations

Stratigraphic studies of the Triassic formations of the Colorado Plateau were planned to obtain information regarding distribution, local and regional variations in lithology, source and character of constituting material, conditions of deposition, and the post-depositional history of the ore-bearing Shinarump conglomerate and associated formations.

During the 1952 field season regional stratigraphic relations of Triassic and associated formations were studied in the Shinarump Cliffs area, Kane and Washington Counties, Utah; Circle Cliffs and Hite areas, Garfield County, Utah; Capitol Reef area, Garfield and Wayne Counties, Utah; and the White Canyon, Red Canyon, and Red House Cliffs area, San Juan County, Utah. The studies were preliminary and conclusions are, therefore, tentative.

Noteworthy results of the work during this period include the following: The Moenkopi formation thins to the northeast, east, and southeast from the Shinarump Cliffs area. The Sinbad limestone member of the Moenkopi was correlated from the Captiol Reef area, where it was identified by J. Fred Smith, southward into the northern part of the Circle Cliffs area, where it has not been previously reported.

The Shinarump conglomerate, although present in all the areas studied, was found to be highly discontinuous. The thickness of the Shinarump conglomerate and the depth and width of its channels into the Moenkopi formation decreased eastward from the Circle Cliffs and Capitol Reef areas to the White Canyon area. The close genetic relation of the Shinarump conglomerate and the Chinle formation has been verified by observations in the Circle Cliffs and Capitol Reef areas. At a few places in these areas greenish-gray claystones, interstratified in the Shinarump conglomerate, were clearly shown to be tongues of the Chinle formation.

The Chinle formation contains several lithologic units that are distinctive over large parts or all of the area studied. Recognition of these widespread units will aid materially in the analysis of the history of Chinle deposition. The lower third of the formation consists predominantly of greenish-gray claystone with interstratified sandstone, and corresponds to the lowest unit of the Chinle in Monument Valley (Gregory's "D" division of the Chinle formation). In the Circle Cliffs, Capitol Reef and the western part of the White Canyon area, a prominent reddish-orange siltstone or sandstone unit overlies the greenish-gray unit. A reddish-brown siltstone or sandstone unit is present at the top of the

Chinle in the Red House Cliffs, White Canyon, and eastern part of the Circle Cliffs area and corresponds to a similar unit in the Monument Valley area (Gregory's "A" division of the Chinle). Beneath this top unit are interstratified reddish siltstones and gray limestones that persist throughout the area studied. These beds correspond in part to a similar unit in the Monument Valley area (Gregory's "B" division of the Chinle).

Studies of Shinarump conglomerate pebbles seem to indicate significant changes in pebble composition, size, sphericity and roundness. The pebble composition in the Shinarump Cliffs is predominantly fine-grained quartz, quartzite, and chert. Eastward from the Shinarump Cliffs to White Canyon fine-grained quartz and quartzite pebbles increase in number and chert pebbles decrease; sphericity and roundness increase; and maximum pebble-size decreases. These changes may reflect real paleogeologic variations or may be a freak of sampling to be checked by future work.

Sedimentary structure studies indicate that the Shinarump conglomerate was derived from a source to the southeast and south of southcentral Utah. These studies also indicate that the prominent sandstone in the lower part of the Chinle formation in the White Canyon area derived its sediment from a similar source in a similar direction.

The sedimentology laboratory is processing samples collected during the 1952 field season. Preliminary investigation and standardization of new analytical procedures to be applied in the study have been completed and will be used throughout the Triassic study.

During the next report period, the stratigraphic studies group will compile data collected during the past field season and, upon completion, submit an interim report summarizing the results. Field studies will be resumed in the spring of 1953 with work concentrated on the study of Triassic formations of the San Refael Swell and Interriver areas of east-central Utah.

Ground-water studies
by L. C. Craig

Ground-water studies were begun in 1950 to determine the present and past ground-water conditions in the ore-bearing rocks of the Morrison formation, and the influence that these waters may have had on the genesis and localization of the ore deposits. Results of this study have been summarized in TEI-161, "Present and past ground-water conditions in the Morrison formation in southwestern Colorado and southeastern Utah," by D. A. Phoenix. This will be transmitted to the Atomic Energy Commission during the next report period.

Ground-water studies during this report period consisted of field and office investigations of the relation of conglomeratic lenses in the basal part of the Brushy Basin member of the loci of uranium deposits in the top sandstone strata of the Salt Wash member of the Morrison. The results indicate in the areas studied that 90 percent of the carnotite deposits observed at the outcrop or discovered by diamond drilling are beneath lenses of the basal Brushy Basin conglomerate or are beneath the projection of such lenses. Only 10 percent of the uranium deposits were not directly overlain by conglomerate or the projection of a conglomerate lens. These results will be transmitted to the Atomic Energy Commission as a TEM report, "Conglomerate strata at the base of the Brushy Basin member of the Morrison formation as a guide to the carnotite deposits of the Morrison," by D. A. Phoenix.

Transmissibility studies made on Calamity Mesa, Montrose County, Colo., during 1950-51, were extended during the summer of 1952 to Outlaw Mesa, Montrose County, Colo., and the relation of rock transmissibility to ore deposits was examined. The results of this work indicate that carnotite deposits occur in rocks of relatively high transmissibility.

Extension of the ground-water program during Fiscal Year 1953 was planned primarily to determine the horizontal and vertical transmissibility relations of all the exposed sedimentary formations on the Colorado Plateau in order to test the capacity of the rocks to transmit ore-bearing solutions to the sites of known deposits. These objectives may permit the definition of routes of transportation by which the ore minerals were introduced to the ore-bearing rocks, as well as permit partial evaluation of the chemical character of the ore-bearing solutions. Preliminary arrangements for the required permeability determinations have been made and the studies will be started as soon as a geologist is available to undertake the work.

Geobotanical studies

Geobotanical research, by H. L. Cannon

The objectives of the geobotanical research project are to investigate and establish the use of indicator plants and absorber plants in prospecting for uranium deposits. The project entails detailed field and laboratory studies of the distribution and habits of all species of plants found in uranium districts and study of the relation of these plants to the geochemistry of ore deposits.

Short reconnaissance studies were made at La Ventana Mesa, Sandoval County, New Mexico, and on Elk Ridge, San Juan County, Utah. At La Ventana Mesa a uranium-bearing coal bed of early Tertiary age is capped by a massive sandstone layer 60 feet thick, which forms the top of the mesa. Preliminary samples of trees growing on the sandstone cap indicate that the trees are rooted in fractures and that uranium is being absorbed from the coal bed below. As a result of the preliminary reconnaissance, the vegetation of the area was systematically sampled to aid in locating ore trends. On Elk Ridge, the ore-bearing Shinarump conglomerate is covered for the most part by talus. Preliminary sampling indicates that uranium is absorbed by trees growing on mineralized portions of the outcrop. Additional sampling is planned for next summer to test further the use of tree analyses in prospecting.

Three short reports were prepared on the results of earlier geobotanical reconnaissance at Temple Mountain, Emery County, Utah (TEM-482); the Marysvale area, Piute County, Utah (TEM-483); and the Great Divide Basin, Sweetwater County, Wyo. (TEM-484). Further geobotanical research is recommended in the San Rafael Swell as a result of the relations between plants and mineralized ground noted at Temple Mountain.

H. L. Cannon presented a paper entitled "Geobotanical methods of prospecting for uranium" to the AIME section meeting in Los Angeles, Calif., on October 24, 1952.

An interim report on geobotanical results in the Yellow Cat area, Thompsons district, Grand County, Utah, is in preparation. The report will present a statistical analysis of indicator plant distribution as related to drilling results. Of the holes in the Yellow Cat area, 93 percent of those drilled in areas of indicator plants were in ground classed as favorable for ore on the basis of geologic criteria. Indicator plants were present near 81 percent of the drill holes containing ore, near 54 percent of the holes containing mineralized rock of sub-ore grade, and near only 12 percent of the unmineralized holes. Plans have been made for further use of geobotanical prospecting by exploration geologists as an additional guide to future drilling in the Thompsons district.

Plans call for completion of a geobotanical handbook by H. L. Cannon in the latter part of fiscal 1953. A large number of drawings of indicator plants already have been made as illustrations for this handbook, which is planned as an illustrated pocket guide for field men interested in learning and using indicator plants. Preparation of a library of pressed plant specimens will be continued in the Grand Junction office for use of all geologists. Results of several reconnaissance investigations will be presented in short reports for transmittal to the AEC. Further research on indicator plants and their growth habits will be carried on in experimental plots near Santa Fe, N. Mex. Field work on the relation of sulfur-indicator plants to soluble sulfates in the soil will be continued in the Yellow Cat area, Grand County, Utah, and on Deer Flats, San Juan County, Utah, in April and May.

Geobotanical prospecting, by P. F. Narten

The principal objective of the geobotanical project in McKinley and Valencia Counties, N. Mex. was to test the use of uranium absorber plants in prospecting the Jurassic Todilto limestone for uranium by sampling and assaying branches of pinyon (Pinus cembroides) and one-seed juniper

(Juniperus monosperma). A secondary objective was to evaluate the use of indicator plants in defining uranium-mineralized ground in the Grants district.

Approximately 3,500 samples of pinyon and juniper trees were collected from the following land division areas in New Mexico in which tree roots might be expected to reflect the location of uranium in Todilto limestone:

Township north	Range west	Sec.
11	9	4,8
12	9	4,9,33,34
13	9	30
13	10	15,16,17,18, 19,22,26
13	11	9,10,11,13, 14,15,24
14	11	18,19,20,21, 28,29
14	12	13,14,15,16,17, 21,22,23,24

About one quarter of the samples were collected for research purposes or to check or define geobotanical anomalies. The results have shown that for practical purposes tree branches are more easily obtained, more uniform in content, and less liable to be contaminated than any other type of tree sample. Other parts of a tree may tend to concentrate large amounts of uranium but the difference is not outstanding. In areas of possible contamination due to mining activity, peeled branch samples were collected.

A content of 1.0 ppm uranium in the ash was used as indicative of mineralized ground. On this basis all known ore bodies or mineralized ground over which trees were sampled were confirmed by the tree branch analyses. In addition, confirmation of geobotanical anomalies was indicated in several areas by later geologic exploration, and mineralized ground is now being found in the one area specifically drilled on tree branch anomalies. A more complete appraisal of the technique must necessarily await the results of the AEC's proposed drilling program or of drilling by private industry on the anomalies outlined. Of particular interest would be exploratory drilling on those anomalies along or near fault trends and in areas where the probable depth to the Todilto limestone is 60 feet or more. A few of these areas were outlined in a field report submitted to the AEC District Geologist, District 6, on October 28 entitled "Preliminary recommendation for drilling based on geobotanical prospecting". Two other field reports citing work and recommendations for exploration on private leases in sec. 26, T. 13N., R. 10 W. and sec. 30, T. 13N. R. 9W., McKinley County were also submitted to the AEC District Geologist on August 29th and October 15.

Detailed studies of indicator plants in the Grants district were limited essentially to the mapping of <u>Astragalus sp.</u> plants on a geologic base map in a one square mile area in secs. 13 and 24, T. 13 N., R. 10 W, and secs. 18 and 19 T. 13 N., R 9 W. The Morrison crops out in this area, which is between two of the largest active mines in the Morrison sandstone. Several favorable areas were outlined, but interpretation is complicated by the high selenium content of the Morrison shales. A primrose (<u>Oenothera caespitosa</u>) found to be associated with <u>Astragalus</u> plants near all known deposits and favorable areas may prove to be an additional indicator plant.

No further field work is planned in the Grants district at the present time. Resampling has been completed of all significant areas except in T. 14 N., R. 12 W. for which no analytical data were available in the field. This township, according to geologic criteria now used by the AEC in the Grants district, is considered to be unfavorable. Recommendations on sections or groups of sections will be submitted to the AEC District Geologist as the analytical information is available, concurrent with the preparation of an interim report. Drilling by the AEC will probably not begin until the spring of 1953 so that an additional report summarizing the value of geobotanical methods of prospecting in the Grants district will be prepared in late 1953.

Resource appraisal
by W. I. Finch

The resource studies are designed to obtain a better evaluation of data on the distribution, reserves, and production of uranium ores on the Colorado Plateau, to assist in providing a basis for the Atomic Energy Commission's policy, to aid in preparing long-range plans for mining and milling operations, and to help in selecting areas for future exploration.

District appraisal studies

The objectives and functions of this project are to compile production and reserve data, to prepare special reserve studies, and to supervise and guide part-time resource studies by exploration and geologic mapping geologists. The compilation of production and reserve data is being assumed by the Grand Junction Exploration Branch of the Atomic Energy Commission, thus eliminating, for the most part, this task from the district resource studies. The project is also processing drill core and other assays and distributing results to those concerned.

During this period the following Preliminary Reserve Statements were prepared: Statements 24, 25, and 26 of reserve blocks A, B, and C respectively, on the Dolores bench, Montrose County, Colo., by D. A. Jobin were transmitted in November as TEM-262, 263, and 264 respectively. TEM-298, "Preliminary report on the uranium and vanadium resources of the Entrada sandstone, western San Juan Mountains, Colo.," by A. L. Bush and Leonid Bryner is in preparation.

Plans call for the preparation of preliminary reserve statements as warranted by the results of exploration. The scope of the district resource studies is being modified to coordinate with resource appraisal plans of the Grand Junction Exploration Branch of the Atomic Energy Commission.

Pre-Morrison resource appraisal

The objectives of the pre-Morrison resource appraisal are to obtain an evaluation of uranium deposits in pre-Morrison formations, particularly the Shinarump conglomerate, and to determine habits of uranium occurrences in pre-Morrison rocks and to compare these with habits of Morrison uranium deposits in hope of establishing factors common to uranium deposits of the Colorado Plateau, with the objective of determining areas favorable for exploration, or areas in which geologic mapping or specialized geologic studies are desirable.

During this reporting period uranium deposits in pre-Morrison rocks were examined in 8 uranium mining districts of the Colorado Plateau. The Yellow John mine, San Juan County, Utah; Lucky Strike mine, Emery County, Utah; Silver Falls mine, Garfield County, Utah; and parts of the Monument No. 2 mine, Apache County, Ariz. were mapped in detail. Selected rock samples were taken for thin and polished sections, stripping film, spectrographic and chemical analysis, and mechanical analysis.

Broad areas generally favorable for ore deposits have been delimited on the basis of ore habits and other geologic criteria in Monument Valley, Red and White Canyons, the Elk Ridge area, the San Rafael Swell, and the Inter-river area. A preliminary report will be written on the general appraisal of deposits of pre-Morrison formations showing these favorable areas and including an account of zoning of deposits and other features. After study of all available data, an interim report of a more detailed and complete nature will be prepared. During 1953, the resource appraisal program will continue to gather data to obtain a better understanding of the resources and habits of uranium deposits in pre-Morrison formations.

Claim map compilation, by N. K. Mobley

After searching of public records and making field checks to locate claims, three claim maps were prepared in March 1952. The claims are plotted on 7½-minute topographic quadrangle maps, which are transmitted as TEM reports. The three completed claim maps are TEM-345, 346, and 347, and cover the Paradox quadrangle, Montrose County, the Gypsum Gap quadrangle, San Miguel County, and the Uravan quadrangle, Montrose County, all in Colorado.

Work is nearly complete on 10 more quadrangle claim maps. With transmittal of these 10 maps, the preparation of claim maps for the eighteen 7½-minute quadrangles in southwestern Colorado will be completed.

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Cenozoic studies
by C. B. Hunt

The Cenozoic history of the Colorado Plateau likely has considerable bearing on the problems of oxidation of the uranium deposits and may bear directly on the problems of their origin and mode of occurrence. Partly with this in mind the General Geology Branch of the Geological Survey has been studying aspects of the Cenozoic history of the Plateau as part of their general geologic studies.

The objectives of the program are to learn as much as possible about:

1. The history of the orogenic and epeirogenic movements to which the Plateau has been subjected.

2. The history, including the mechanics of intrusion, differentiation, and pneumatolytic processes in and about the igneous bodies on the Plateau, and

3. The stratigraphy of the glacial, alluvial, colluvial, and eolian deposits on the Plateau.

A summary of present knowledge of the Cenozoic history of the Plateau is being prepared.

Orogenic and epeirogenic movements

The orogenic structures that may have contributed to localizing some of the uranium deposits are being mapped as part of the geologic mapping program; dating of the movements on these structures is a primary concern of the Cenozoic studies.

Fairly good evidence has been found to indicate several stages of orogenic deformation during the early Tertiary. Around the edges of the

Plateau are indications of several stages of late Tertiary and Quaternary orogenic deformation. The epeirogenic uplift of the Plateau is believed to have started in the Oligocene or early Miocene. Until that uplift occurred the Plateau was a lowland, in large part with interior drainage.

Stratigraphy of glacial and other Quaternary deposits

Stratigraphic studies of the Quaternary deposits seek to develop information about the climatic changes and resulting changes in ground-water level and type of weathering that may have affected the uranium deposits. Along the Colorado River, for example, near the mouth of White Canyon, extensive spring deposits were found interbedded with gravel fill believed to be of Wisconsin age. The spring deposits indicate a very high ground-water table during that pluvial cycle.

Field work during 1952 confirmed the reported scarcity of pre-Wisconsin glacial deposits in the High Plateaus of Utah. Quaternary deformation in the High Plateaus is indicated by faulted and tilted Quaternary deposits and is supported by present seismic activity in the region. The Wasatch Mountains of central Utah were uplifted about 1,000 feet in Pleistocene time; this uplift together with the scarcity of pre-Wisconsin glacial deposits in the High Plateaus suggests that the High Plateaus may have been uplifted considerably during Quaternary time.

Intrusions and volcanism

A geologic map of the Henry Mountains region, Utah, was published as Oil and Gas Investigations Map OM-131 in June 1952. Field mapping in the La Sal Mountains, Utah, was completed during the summer and a preliminary general geologic report and map is being prepared for transmittal to the Atomic Energy

Commission. TEM-354, "Radon in the Dillon tunnel in Miner's Basin, north La Sal Mountains, Grand County, Utah," by Henry Faul and C. B. Hunt, was transmitted to the Atomic Energy Commission in September 1952. The source of the radon in the Dillon tunnel in the north La Sal Mountains still is not known. Rock samples of the hydrothermal and differentiation series are being analyzed for uranium and other trace elements; these analyses may show a pattern of occurrence of the radioactivity. Field work in the La Sal Mountains indicates that the alkalic members of the differentiation series generally give a higher than background count with a geiger counter.

Mineralogic studies

General mineralogic studies, by L. B. Riley

The objectives of the mineralogic studies program are to identify the minerals of the uranium deposits of the Colorado Plateau and to determine the composition, structure, distribution, and paragenetic relationships of the minerals in order to contribute to an understanding of the habits and origin of the deposits.

A primary objective of the field season of 1952 was to obtain mineral samples with a wide geographic and stratigraphic distribution on and near the Colorado Plateau, in order to determine common associations of minerals and types of ores. Mineral sample suites were collected in all the major mining districts. This mineral sampling was combined in part with the collecting of samples suitable for isotopic age determinations by L. R. Stieff and T. W. Stern. In addition, a special mineral collection was made for an intensive study by D. H. Johnson of the mineralogy at and near the Monument

No. 2 mine, in Apache County, Ariz. A preliminary collection of ore specimens at Pumpkin Buttes, Wyo., was made for comparison with the Plateau ores.

In the course of field work, rich black uranium ore was observed to occur in environments protected from oxidation, such as at depth, under a considerable cover, near the heads of canyons, or well within larger oxidezed ore bodies. The rich black uranium ore was commonly surrounded by a black vanadium-rich ore. The association of the black ore with sulfides was observed in enough places to suggest a genetic relationship between the two.

The study of the mineralogy of these black ores has progressed satisfactorily, although much remains to be done. Uraninite is widespread and commonly associated with carbonaceous material. A black tetragonal uranium mineral, tentatively named "coffinite," first discovered in a sample collected for isotopic age studies from the Arrowhead mine, TEI-280, has been found in several more localities on the Plateau; this mineral is a silicate, but probably contains some arsenic and vanadium. One occurrence is at the Bowknot locality, Green River district, Utah, in the Shinarump formation; its other known occurrences are in the Morrison formation. Another newly-discovered black mineral, tentatively named "lumsdenite," has been isolated from samples from the La Sal mine, Gateway district, Colo.; it is a vanadium mineral, with a blade-like structure.

Two other minerals that are being studied rather intensively are melanovanadite from the mines in the Lukachukai Mountains area, Ariz., and "zippeite" from Capitol Reef, Utah. Melanovanadite was previously known only from Minasragra, Peru. The "zippeite" from Capitol Reef differs from "standard" zippeite in its X-ray powder pattern, and its optical properties indicate that it is monoclinic rather than orthorhomic. The first occurrence of novacekite in the United States was discovered in a sample collected in the Laguna area, N. Mex.; this uranyl arsenate may be an indicator of above-average concentrations of arsenic. Samples collected from the Huskon claim, near Cameron, Ariz., show a considerable concentration of cobalt and nickel.

Reports by A. D. Weeks summarizing the mineralogic studies (TEM-431) and the clay studies (TEM-437) were transmitted to the Atomic Energy Commission in July 1952. These reports, together with a report on a study of some Jurassic and Cretaceous claystones and siltstones, and a note on the occurrence of bayleyite, were abstracted in TEI-280. A report, "New occurrences of rauvite," by A. D. Weeks, is now being edited. Two papers being written at present are: "Identification and occurrence of uranium and vanadium minerals on the Colorado Plateau," by A. D. Weeks and M. E. Thompson, and "Description and occurrence of montrosite," by A. D. Weeks; the latter may include or be accompanied by an article on the structure of montrosite by H. T. Evans, who has found that its structure is similar to that of diaspore and geothite, and that its correct formula is VO(OH) or (V,Fe)O(OH).

A paper titled "Mineralogic studies on the Colorado Plateau" was presented by A. D. Weeks at the Geological Society of America meetings in Boston Nov. 12-15, 1952. An exhibit of Colorado Plateau minerals was shown during this meeting.

Work planned consists of continued study of the mineralogy of material collected on and adjacent to the Colorado Plateau. Several discussions between various members of the Geochemistry and Petrology Branch, have been held under the direction of Robert M. Garrels, toward undertaking research studies on vanadium clays, vanadium oxides and uranium-vanadium compounds, especially their structure, synthesis and stability relationships, and these studies will be integrated with the mineralogic studies.

Distribution of elements by E. M. Shoemaker

The distribution of elements project is planned to investigate the relationship between uranium deposits, host sedimentary rocks, other types of ore deposits, and igneous rocks in an effort to determine criteria for recognition of areas containing ore deposits. In addition, special search is being made for new geologic environments favorable for uranium deposits and for new types of uranium deposits. Preliminary studies have yielded encouraging results which are summarized in TEI-275, "Distribution of ore deposits and spectrographic analyses of some rocks and ores on the Colorado Plateau," by E. M. Shoemaker and L. B. Riley, in preparation. A map of the "Uranium region of the Colorado Plateau," by E. M. Shoemaker and R. G. Luedke, showing the ore deposits of the area, is being issued as TEI-279. This map was originally planned to accompany TEIR 275, but was issued separately so it could be placed on open-file.

The distribution of elements program is divided into three separate phases: (1) distribution of elements in the bedded ore deposits, (2) distribution of elements in the sedimentary rocks, and (3) distribution of elements in the igneous rocks. Although the work of the program was recessed from May 31 to September 15, progress has been made in all three phases. A file of about 5,000 pulp samples of ore shipments to the mills, representing about 400 uranium deposits, has been collected and catalogued. Processing of these samples for analysis has begun.

A suite of 30 new analyses of Jurassic and Triassic sandstones has been obtained from samples collected by the stratigraphic studies program. About 70 samples of sedimentary rocks, ranging in age from pre-Cambrian to Eocene, have been collected in the field. The study of igneous rocks has included reconnaissance study of the Ute Mountains, La Plata County, Colo., to guide sample collection, as well as collection of about 150 samples of igneous rocks representing most of the laccolithic intrusions in the northern and central part of the Plateau, part of the lamprophyre intrusions of Navajo-Hope Reservations, and most of the volcanic fields on the periphery of the Colorado Plateau. Most of the areas of outcrop of pre-Cambrian rocks on the Plateau have been visited and sampled.

Noteworthy results of the work since June 1, 1952 include the delineation of the structure of the Ute Mountains and the discovery of a zonal arrangement of ore metals adjacent to a dike of pyroclastic lamprophyre at Garnet Ridge, Apache County, Ariz. The Ute Mountains contain about 30 major laccoliths radiating from two stocks. Sulfides and ore deposits are found chiefly in one laccolith and not in the stocks. Spectrographic analysis of drill core samples from the Garnet Ridge area have revealed a well-defined distribution pattern of metals normally associated with uranium ore adjacent to a dike of comminuted minette. Small pockets of rich uranium ore occur along the dike which is related to a diatreme in an arrested stage of development.

Field work will be continued until late December 1952. During the next six months samples collected will be prepared and analyzed spectrographically and chemically. Many samples will be studied petrographically and by other means as well. A progress report summarizing the results of this work will be prepared by July 1953.

Geophysical investigations
by R. A. Black

Geophysical investigations have been carried out in connection with the Geological Survey's search for uranium deposits of the Colorado Plateau since 1949. Studies have been made to determine the applicability of various geophysical methods of prospecting to the solution of geologic problems connected with the occurrence of uranium deposits. As a result of magnetic, geothermal, and electrical studies, it was determined that electrical methods are most applicable as an aid to prospecting for uranium deposits in the Morrison formation. The recent extension of geologic investigations to Triassic areas has provided new areas for geophysical investigations and new problems to which various geophysical techniques can be applied.

Natural potential, electrical resistivity, and gravity surveys were made on Koley Black Mesa, Monument Valley, Ariz. The aim of this work was to determine if these geophysical methods could be used to locate and trace Shinarump channels cut into the Moenkopi formation. Preliminary interpretation of the resistivity data indicates that electrical resistivity depth measurements can be used to determine the trend and approximate shape of channels. Interpretation of the natural potential data has not progressed far enough to permit evaluation of this method for channel location. Preliminary results of the gravity data show small anomalies which may correspond with the channel trends.

Electrical measurements using commutated current were also made on Koley Black Mesa. Difficulty had been experienced here with direct current electrical methods due to high near-surface resistivities. A possibility existed that resistivity measurements made by using commutated current and balanced electrodes would be more amenable to solution by theoretical means. Comparison of the two methods indicated that the curve shapes were substantially the same, but that smoother curves were obtained with commutated current.

Electrical resistivity measurements were made in a one and one-half square mile area near the Monument No. 1 mine in Monument Valley, Ariz., in order to find, if possible, a continuation of the Monument No. 1 channel. These data have not been processed as yet.

Electrical well-logging operations have been carried out in selected mining areas in southwestern Colorado and southeastern Utah. Preliminary results indicate that a definite contrast exists between unfavorable, favorable, and mineralized sands in one area. Results from the other areas have not been determined.

Field work has terminated until next spring. The winter will be spent in computation of data and the preparation of reports on geophysical investigations at La Sal Creek, Grand County, Utah; Koley Black Mesa, Monument Valley, Ariz.; and Monument No. 1 mine, Monument Valley, Ariz. A summary report on electric well-logging operations is in preparation.

Work planned for the next field season includes refraction seismic tests over channel area, gravity and magnetic surveys in connection with regional geologic problems on the Colorado Plateau, electrical studies in selected Triassic areas, and electric well-logging in selected Morrison areas.

Original-state core studies
by G. E. Manger

The objective of the original-state core study is to provide basic data on the physical and chemical properties of ore-bearing and country rock where the amount and composition of the interstitial water in the rock have not been changed radically by the flushing action of a water-circulating drilling medium. Basic data such as the percent interstitial water saturation, chemical composition of the interstitial water and the host rock, and the porosity, permeability and electrical conductivity of the rock should assist materially in the interpretation of data obtained by current geophysical and geologic exploration. It is possible, too, that such data may reveal other relationships that would suggest new or modified techniques of exploration.

During the summer of 1952, two holes about a quarter of a mile apart in the Long Park area, Montrose County, Colo., were core-drilled to a depth of approximately 300 feet. Oil-base-mud core drilling was used to recover cores containing the original (interstitial) water, and air core drilling was used principally to obtain rock specimens suitable for resistivity and elastic constant measurements. Gamma-ray and electrical logs were obtained for the two drill holes. When completed, the chemical and petrophysical analyses of the cores will be evaluated for significant interrelationships and also for correlation with the logs. Laboratory work so far has been confined to a measurement of the radioactivity of the core samples.

Core recovery by air drilling was good and by oil-base mud drilling was excellent. For example, in drill hole LP-530, complete recovery of oil-base mud cores was obtained in the interval from 243 to 293 feet.

Core drilling demonstrated a quasi-permanent ground-water level at 200 feet in the structurally higher and locally well-mineralized drill hole, whereas the structurally lower and poorly mineralized drill hole was found to be dry to the final depth of 292 feet. The drilling demonstrated that much or all the water causing "collars" of drill cuttings in one of the drill holes was derived from condensation of water vapor from the drilling air.

A progress report, TEM-509, by G. E. Manger of the Geological Survey and George L. Gates of the U. S. Bureau of Mines, describing last summer's field results, is being prepared for transmittal to the Atomic Energy Commission. Laboratory tests, planned for the next few months, will be done by the U. S. Bureau of Mines in San Francisco, Calif., and College Park, Md., by the Geological Survey in Washington, D. C. and Grand Junction, Colo., and probably by the Pennsylvania State College. Another report will be issued upon the completion of these investigations, or, if it appears advisable, upon completion of a part of them. Whether or not more core drilling will be done next summer depends considerably upon the results of the laboratory investigations over the next few months.

Pumpkin Buttes area, Powder River Basin, Johnson and Campbell Counties, Wyoming
by M. L. Troyer

The objectives of the work are: to study distribution of rocks in which uranium occurs by geologic mapping and the measuring of stratigraphic sections; to study the habit of occurrence of uraniferous deposits, and to use such knowledge as guides in outlining areas favorable for the occurrence of uranium deposits.

Of the 400 square miles comprising the Pumpkin Buttes area, approximately 100 square miles were mapped in some detail on aerial photographs, and 120 square miles were mapped by reconnaissance methods. About 7000 feet of stratigraphic section was measured. Approximately 300 localities were examined on the ground where anomalies were reported by U. S. Geological Survey and Atomic Energy Commission planes equipped with scintillation detectors. Some of the larger uraniferous deposits were mapped in detail. Physical exploration in the area consisted of about 2700 feet of drilling with a jeep-mounted auger, and excavating about 5000 cubic yards of earth by bull-dozing.

Uraniferous deposits in the Pumpkin Buttes area occur in thick, lenticular, cross-bedded, reddish-gray to pink, medium- to coarse-grained sandstones 500 to 950 feet above the base of the Wasatch formation of lower Eocene age. Areally, the known deposits appear to be concentrated in a north-south belt 30 miles long and 15 miles wide.

Uraniferous deposits discovered in the area are of two types: (1) small irregular shaped concretionary masses containing much iron and manganese and showing a high uranium content, and (2) disseminated uranium minerals with little or no iron and manganese. Type(2 deposits are larger but of lower grade than type (1); and were discovered late in the season. These disseminated-type deposits are more nearly like the Colorado Plateau deposits than any found earlier in the season in the Pumpkin Buttes area. It is hoped that this type will prove to be more and extensive than type (1).

The total measured ore reserves are 60,000 lbs. containing 2000 lbs. of uranium. The total indicated ore reserves are 400,000 lbs. containing about 13,000 lbs. of uranium. Inferred reserves have not been calculated because data necessary have not been compiled and interpreted completely.

The following lithologic features are commonly associated with uranium deposits in this area and are useful guides to favorable ground:

1. The presence of reddish-gray to pink sandstones.

2. The presence of carbonaceous material in or below such sandstones.

3. The presence of manganese. (True only in the type (1) deposits).

More detailed geologic mapping and detailed stratigraphic work should be done to assist in determining the origin of the uraniferous deposits and to outline the favorable area for future prospecting.

Black Hills, South Dakota
by W. E. Bales

The objectives of this project are to develop criteria for the recognition of ground favorable for the occurrence of uranium within the sedimentary formations of the Black Hills. These criteria are being developed by both detailed and regional geologic investigations of the known occurrences of uranium in the southern Black Hills. It is hoped that through the application of such criteria to the reconnaissance and exploration of the

Black Hills area, the known deposits may be materially extended and new deposits of uranium found.

The formations of the Inyan Kara group are composed of sandstone, siltstones, and claystones deposited in a terrestrial flood plain environment. Each formation varies widely in lithology both vertically and areally.

The uranium occurrences are in permeable sandstones which are both overlain and underlain by an impermeable layer of claystone which may range in thickness from a parting to a bed of considerable thickness. The economic carnotite deposits occur most frequently in thin continuous layers of sandstone (from 1 to 5 feet in thickness), but they also occur in thicker, more massive sandstone such as the deposits in the lower half of the Lakota formation in Craven Canyon. The latter deposits, however, are less likely to be economically minable and are more likely to be spotty and of lower grade than deposits in thinner bedded sandstone.

Thus with the extreme lateral facies changes that are known to occur within the Inyan Kara group, and the varied sequences of deposition it appears that economic concentrations of uranium may occur throughout the stratigraphic section of the group and at various places within the sedimentary rocks of the southern Black Hills.

Carbon is widely distributed within the group either as free carbon (plant imprints, wood remains) or in the form of coal or other hydro-carbons; however, it bears no consistent relationship with the uranium deposits.

Oxides of iron are intimately associated with the uranium occurrences. Iron sulfides (pyrite) have been noted in unweathered non-mineralized sediments and may be a source of an acid ore-carrying solution.

A halo of "pink" hematite stained sandstone around the deposits of carnotite is usually more or less well developed, and may offer a larger target for physical exploration and a useful criterion for prospecting.

Plans for future work in this area call for a continuance of regional stratigraphic studies in the district to determine the more significant characteristics of the uranium-bearing formations in comparison to the non-ore bearing formations, and determination of the criteria of ground favorable for uranium occurrences in particular portions of a formation.

It is planned to continue geologic investigations of the larger uranium deposits in the Edgemont area as they are developed to find out as much as possible about the characteristics of the uranium occurrences and the relationship of these occurrences to their host rock.

Plans also call for continuance of geochemical and mineralogic investigations of uranium occurrences with reference to (1) the mode of origin of the metals, and (2) conditions of transportation and precipitation to assist in the continued development of criteria of favorability for the occurrence of uranium deposits.

Detailed geologic examination of occurrences of disseminated uranium minerals in the Minnelusa formation will be undertaken even though the known occurrences are not, at present, of economic significance. These occurrences contain considerable quantities of submarginal ore and may extend over a much larger area than is now known.

SEARCH FOR AND GEOLOGY OF URANIUM IN VEINS, IGNEOUS ROCK, AND RELATED DEPOSITS

General geologic studies

Relation of uranium to post-Cretaceous vulcanism
by R. R. Coats

This project, having for its purpose the investigation of the relationship between uranium and post-Cretaceous vulcanism, was initiated as a result of the observed apparent close geographic relation (Kaiser and Page, TEI-168, p. 11) between Tertiary volcanic rocks and structurally controlled uranium deposits in the southwestern part of the United States. Some of these uranium deposits occur in, or appear from the structural relationships to be genetically related to intrusives of Laramide or later age (King, et al, TEI-168, p. 18).

Field work was commenced by the writer on September 16, and suspended on November 11. Work was performed in Utah, Oregon, Washington, California and Nevada.

Because of the great scope and indefinite limits of the project as stated, it was at once apparent that certain selected aspects of the problem should be attacked first, in order that results from the earlier parts of the work might be applied later. It seemed probable that three aspects of this problem would be most amenable to attack and most likely to yield results useful in further work on the broader problem of the search for and study of uranium deposits. Studies of each of these several aspects are not mutually exclusive, but can, in some measure, be carried on simultaneously. The three aspects are: (1) regional variations in the primary distribution of uranium content of igneous rock bodies and its relation to variation in distribution of other elements; (2) primary variations in the distribution of uranium within individual igneous rock masses; and (3) epigenetic variations in the distribution of uranium in igneous rock bodies.

Methods that are or will be used in this project include: (1) field examination and sampling of bodies of selected types of igneous rock; (2) chemical, spectrographic, radiometric and petrographic analyses on samples collected from such rock bodies, and (3) chemical and spectrographic studies on minerals genetically associated with post-Cretaceous vulcanisn.

Because earlier studies have shown that rhyolites and granites, i.e., the siliceous pole of differentiation, generally have the highest content of radioactive elements, it was determined to concentrate preliminary work on rhyolitic rocks. The level of radioactivity in basic rocks is so low that regional variations in primary radioactivity would be of the same order of magnitude as random fluctuations in counter readings. Any study of such rocks would require extensive and careful sampling, and field radiometric measurements would necessarily have to be more time-consuming than would be the case if one were dealing with rocks having a generally higher level of radioactivity.

Because some possible causes of variations in radioactive content of rock masses, such as the possible escape of radioactive elements during crystallization, or as a result of unrecognized post-consolidation alteration, could be avoided by using glassy rocks, or glassy phases of rocks, primary emphasis was placed upon the examination and sampling of glassy rocks in the search for possible regional variations. Local variations were sought in both glassy and holocrystalline or hypocrystalline bodies. Field examination was done in part with the aid of an NICC Geiger-Müller counter, Model 2610A, and in part with a Nuclear Research Corporation scintillation rate-meter. The latter is an instrument of a new design, and the long-term reproducibility of its measurements is doubtful. For this reason, firm conclusions on regional variations in relative radioactivity must await the results of laboratory work on the samples collected. The scintillation meter is probably more reliable in measuring local variations over short periods of observation. Background with this counter was about 0.008 mr/hr.

Rhyolitic rocks were studied and samples collected in the following areas: Beaver and Juab Counties, Utah; Lander, Humboldt, Pershing, Esmeralda, Washoe and Storey Counties, Nevada; Lake, Baker and Deschutes Counties, Oregon; Chelan County, Washington; Modoc, Sutter, Lake, Napa, San Benito, Kern, San Bernardino, Inyo, and Mono Counties, California. Rocks studied range in age from Eocene to Pleistocene, possibly Recent in some cases.

Certain tentative conclusions are apparent as a result of the work to date, but may need revision in the light of further laboratory and field work: (1) In a given small area, the younger rocks seem generally to be more radioactive than the older. (2) Total range of variation in <u>certainly</u> unaltered rocks was from 0.008 to 0.028 mr/hr., as measured with the scintillation rate-meter. (3) Glassy, unaltered flows showed highly uniform radioactivity from place to place within a single formation. (4) Apparently unaltered, glassy volcanic domes also appeared very uniform throughout, but less so than flows. (5) Lithoidal (crystalline) intrusives showed significant variation from place to place. This may be related to epigenetic alteration, or to escape of end-phase fluids containing radioactive elements. (6) Pleistocene extrusives, altered by hot spring or solfataric action, showed either no change in radioactivity, or a slight reduction, as compared with the unaltered rock. This is interpreted to mean that uranium has, in general, been deposited from hydrothermal solutions in zones deeper than the extremely near-surface solfataric zone. Several sulfur, and sulfur-alunite or alunite deposits of solfataric type were examined. Sulfur samples were collected with a view of determining whether there exists any regional variation in the content of trace elements, such as selenium, that are in some areas associated with uranium. Radioactivity in such deposits was uniformly low; this does not preclude the possibility of the existence of some relation between uranium deposition and a deeper-seated type of alunitic mineralization. (7) In some places, rhyolitic intrusives, such as volcanic necks, showed apparent ranges of the order of 100 percent in radioactivity from unaltered rock to bleached and argillized (?) rock, the position of the alteration being controlled by post-consolidation structural features.

The sampling and field examination of post-Cretaceous volcanic rock, to determine the possible existence and nature of regional variation, will be extended to possibly significant areas not yet covered. The study of the relationship of the type of alteration to radioactivity in rhyolitic intrusives will be continued and extended.

After the extensive phase of the project is completed, it may appear desirable to enter a more intensive study of selected areas.

Zonal relations of uranium deposits in metalliferous districts
by B. F. Leonard

As originally stated, the objectives of this project are to:

(1) To test the validity of the writer's ideas on the zonal position of uranium deposits in metalliferous areas (TEI-270). The salient features have been presented principally in a report by King, Leonard, Moore, and Pierson and in a talk delivered at the recent meetings of the Geological Society of America by Leonard.

(2) To find and make appropriate investigations of new uranium deposits. The emphasis of the project is on the development of geologically-based prospecting guides to delimit <u>areas</u> most favorable for the occurrence of uranium deposits within metalliferous districts. Knowledge of the local geologic factors must be applied to delimit especially favorable areas within generally favorable zones. There is little likelihood of ever being able to pin-point a specific uranium deposit by using so broad a concept as zoning; for, at best, knowledge of mineral zoning is a statistically-based guide, not an infallible or absolute guide. Uranium deposits are not confined exclusively to metalliferous

districts, or at least not to districts from which considerable quantities of metals have been produced. Uranium deposits in non-metalliferous districts fall outside the scope of the current investigation, though eventually it may be possible to relate such deposits to broader patterns of mineral zoning.

The factual data obtained during the report period have come from two sources: (1) studies supervised and assisted by the writer; and (2) studies carried out by the writer's colleagues.

(1) A systematic radiometric reconnaissance of part of the North Gilpin County mining district, Colo., was undertaken. The results have been reported by Campbell and Schafer. They found no uranium deposits of immediate economic interest. Uraninite was identified from one deposit, where it was present as a trace. The district shows a complex pattern of mineral zoning crudely analogous to that at Central City. Veins of pyritic copper-zinc-lead type have roughly three times as many occurrences of anomalous radioactivity as veins of pyritic gold and pyritic gold-copper type. Moreover, most of the highest anomalies in the district are concentrated in areas of pyritic copper-zinc-lead veins. These facts are consistent with observations made by other workers in the Central City district. Possibly the apparent lack of economically significant uranium deposits in the area investigated by Campbell and Schafer is related to the scarcity of economically important base-metal deposits in the district.

(2) Recent discoveries of radioactive deposits in the Central

City, Fall River-Dumont, and Freeland-Lamartine districts have come from the intermediate zones between central pyritic gold areas and peripheral silver-lead-zinc areas. The relations are consistent with those previously known or inferred. (Data from P. K. Sims, R. H. Campbell, J. E. Harrison, F. B. Moore, J. D. Wells, and members of the Atomic Energy Commission's Denver Exploration Branch).

Results and conclusions

1. In general, and mostly by indirect means, the two objectives have been realized for a certain class of deposit--zoned complex base-metal deposits dominantly of mesothermal character--for a restricted area (central part of the Front Range mineral belt).

2. A district in which the zonal pattern is similar to that at Central City but somewhat more complex still has the bulk of the anomalous radioactivity, and the bulk of the faintly promising uranium deposits, in the copper-zinc-lead zone. (Inference from work of Campbell and Schafer, 1952).

3. A district may show a well-defined, if complex, zonal pattern and still apparently lack uranium deposits of economic value, even in an area generally favorable for the occurrence of uranium. (This is entirely expectable. The inference is drawn from work of Campbell and Schafer, 1952).

4. Relations of pitchblende and copper sulfides are particularly instructive. In the Front Range, the zone of pyritic copper deposits, with or without appreciable gold, is generally unfavorable for pitchblende; and the zone of silver-lead-zinc deposits is either unfavorable or less favorable.

But the zone of copper-zinc-lead deposits appears especially favorable--i.e., OVERLAP of copper with zinc and lead; pitchblende in zone of overlap.

In Cornwall, England, pitchblende deposits are definitely restricted to the copper zone. Little economically-significant zinc and lead accompanies the copper, and no pitchblende deposits have been found in the main zinc-lead zone, where copper is rare or absent--i.e., NO OVERLAP of copper with zinc and lead; pitchblende in copper zone.

The relation of uranium and copper has long been thought especially significant. More data on this interesting relation will be sought.

Four kinds of investigation are planned for the next report period:

1. Continued correlation of data on distribution of anomalous radioactivity and pitchblende deposits, relative to hypogene zoning in selected mining districts of the Front Range mineral belt, Colorado.

2. Limited studies of the paragenetic sequence of minerals in selected pitchblende-bearing deposits of the Front Range mineral belt.

3. Compilation of data on hypogene zoning of hypothermal, mesothermal, and epithermal ore deposits especially of the western United States. Preliminary attempts will be made to relate known occurrences of radioactive material to the patterns of metal distribution.

4. As circumstances permit, field checking of the distribution of anomalous radioactivity in one or more zoned districts in the West or Southwest.

Reconnaissance

San Juan Mountains, Colorado
by C. T. Pierson, W. F. Weeks, and F. J. Kleinhampl

Radiometric reconnaissance in the San Juan Mountains, Colorado begun in 1951 by W. S. Burbank and C. T. Pierson, was resumed in 1952. The field work was recessed on December 1, 1952.

The purposes of this work are: (1) to determine what physical exploration will be desirable in the search for commercial deposits of uranium in the districts in which uranium was found during 1951; (2) to outline new districts wherein a detailed search for uranium might be profitable; and (3) to determine the environments of the individual uranium occurrences by field and laboratory work (petrographic, mineralogic, chemical, and spectrographic) and relate these to the major patterns of ore deposition within the given district. Objectives (1) and (2) are discussed below except for possible recommendations for physical exploration which are to be given in a following report.

Radiometric reconnaissance for fiscal year 1953 was scheduled for the Upper Uncompahgre, Red Mountain, Mt. Wilson, Rico, and La Plata mining districts. Detailed work upon which possible recommendations for physical exploration will be based has been completed in the Upper Uncompahgre and Red Mountain districts. About three-fourths of the Mt. Wilson district has been covered and the results are essentially negative radiometrically. Because of the lack of time only one radioactive locality has been visited in the Rico district, and the La Plata district still remains to be tested.

A few mines or mine dumps have been radiometrically examined in each of the following districts: Sneffles, Mineral Point, Telluride, and Iron Springs (Ophir).

Upper Uncompahgre mining district, Ouray County

In the Upper Uncompahgre district pitchblende, found in 1951, occurs near Bear Creek Falls in a black slate member of the Uncompahgre formation of pre-Cambrian age. Channel sampling and detailed structural mapping of the occurrence have been completed, but the reserve, which is probably small, has not yet been calculated.

Radiometric traverses totalling approximately 16 miles have been made along the slate and quartzite bands of the Uncompahgre formation, but the only result was the discovery of very slight radioactivity in the Dunmore mine. In addition, about 5.0 miles have been traversed along the formations on either side of the Ouray fault, which separates the Uncompahgre formation from the Paleozoic formations. The results are radiometrically negative except for the previously reported radioactive tufa deposit just north of the Ouray fault. About 8 more miles of traverse will be needed to give adequate coverage of the Uncompahgre formation, but the priority for this work is not high.

In the Mineral Farm area of silver-lead limestone-replacement ore bodies, about 1800 feet of radiometric traverse was made, and one mine and about 12 mine dumps were tested for radioactivity. All results were negative.

Red Mountain mining district, Ouray and San Juan Counties

In 1951 pitchblende was found in the Red Mountain mining district.

The radioactive deposits consist of "chimney" ore bodies in volcanic breccia pipes, veins, and adjacent wall rocks. All of the deposits are in rocks of the Silverton volcanic series of Miocene age and have been mined extensively for rich copper-lead-silver ore.

Radiometric reconnaissance in the Red Mountain district, has been completed. No commercial deposit of uranium has been found, but in view of the fact that about 11 mines or mine dumps show significant radioactivity (maximum uranium content yet known is 0.16 percent) the possibility exists that a commercial uranium deposit may be found by physical exploration methods, which may be proposed later.

Mt. Wilson mining district, San Miguel and Dolores Counties

Radiometric reconnaissance has been made of part of the Mt. Wilson mining district. Most of the mines and mine dumps in Silver Pick, Upper Bilk, and Navajo basins have been examined. Mines in lower Bilk, Elk, Magpie, and several unnamed basins have not been examined. All of the mines examined are essentially radiometrically negative with the exception of one mine in Navajo basin which contains radon gas.

About two weeks will be needed to complete the radiometric reconnaissance of the Mt. Wilson district, including sampling of the mine containing radon gas. Priority for the work is not high because of the predominantly radiometrically negative character of that part of the district already tested.

Rico mining district, Dolores County

At the suggestion of R. U. King of the Survey, the A.B.G. mine (at which radioactivity has been reported by N. Harshman of the Survey) was examined. The accessible workings are radiometrically negative, but a small amount of moderately radioactive galena-sphalerite limestone-replacement ore was found on the dump.

Additional radiometric reconnaissance in the Rico district is desirable in view of the above noted radioactivity.

Other mining districts

No work has been done in the La Plata mining district, La Plata and Montezuma Counties, although this district should be a favorable place for radiometric reconnaissance because of the variety of types of ore deposits and because of the complexity of the ore mineralogy.

Several mines or mine dumps in Richmond and Yankee Boy basins, Sneffles mining district, Ouray County, have been tested for radioactivity. All results are negative except for slight radioactivity noted in the Campbird mine. Additional reconnaissance in the district will be done if time allows.

Four mine dumps have been tested in the Mineral Point mining district, San Juan County. Three are radiometrically negative, but moderately radioactive ore was found on the dump of the Syracuse Pride mine. Additional reconnaissance is planned in this district because of the radioactivity noted above.

In the Telluride mining district, San Miguel County, about 20 percent of the accessible workings along the Montana vein were radiometrically traversed. One mildly radioactive occurrence was found. Additional radiometric reconnaissance in the district may be desirable.

In the Iron Springs (Ophir) mining district, San Miguel County, several mines and mine dumps were found to be radiometrically negative. About ten more mines or mine dumps may be tested to provide an adequate radiometric coverage of the district.

Plans

Work during the next six months will consist of preparation of a report on the field work, laboratory study of radioactive specimens from the districts covered, and planning and preparation for new field work.

Central Mineral Belt, Colorado
by M. G. Dings

Field work pertaining to radiometric reconnaissance in the Central Mineral Belt has been completed in the Garfield and Taylor Park quadrangles of west-central Colorado, which contain about 450 square miles, and in a small area of about 5 square miles centering around Montezuma, Summit County, Colorado, which lies about 20 miles southwest of Idaho Springs.

The Garfield-Taylor Park region contains many rock types, strong geologic structures, and a variety of ore deposits. The value of the ores is chiefly in gold, silver, lead, and zinc contained in replacement bodies in dolomite and in shoots in fissure veins. Four radioactive deposits were found; however, they are of low grades and tonnages, are widely separated in space, and occur under a variety of geologic conditions. The reconnaissance study indicates that there

[redacted]

is little likelihood of obtaining significant radioactive ores from this region. No further geologic studies are warranted at present.

The Montezuma area contains pre-Cambrian gneiss cut by a Tertiary stock of quartz monzonite. A northeast-trending belt of fissure veins cut the gneiss and stock, and these have yielded ores whose values have chiefly been in silver, lead, and some zinc and gold. Two radioactive anomalies along short distances in two different veins were found; but the indicated tonnage is small and the uranium content is very low. The immediate area around Montezuma therefore does not warrant additional geologic study.

District studies

Colorado Front Range

The principal objectives of the current investigations in the Colorado Front Range are to (1) find uraniferous deposits, (2) determine the geologic setting of the deposits, (3) define ore guides and controls, (4) determine, if possible, the origin of the uranium, and (5) evaluate the uranium resources. To accomplish these objectives an area of 65 square miles between Georgetown and Central City is to be mapped in part on a scale of 1:6,000 and in part on a scale of 1:24,000 (fig. 4). Detailed geologic mapping of accessible mines and radiometric examination of mine dumps and workings will be done in conjunction with the areal geologic mapping.

During the past six-month period geologic mapping was carried on by three field parties in separate areas in the region--Central City district,

[redacted]

[illegible] radioactive [illegible] this [illegible] at present.

[illegible] area [illegible] pre-Cambrian gneiss cut by a few [illegible] pegmatites. [illegible] veins cut the gneiss and [illegible] yielded [illegible] whose values [illegible] silver, lead [illegible] gold [illegible] were found [illegible] content is very low. The [illegible] area around [illegible] warrant additional [illegible]

[illegible] Studies

Colorado Front Range

The principal objectives of [illegible] investigations in the Colorado Front Range are to (1) find [illegible] areas, (2) determine the [illegible] of [illegible] (3) [illegible] and controls, (4) determine [illegible] (5) evaluate the [illegible] resources. To accomplish [illegible] an area of [illegible] square miles [illegible] mapped [illegible] on a scale [illegible] on a scale of 1:24,000 [illegible] Detailed geologic [illegible] mines and [illegible] were [illegible] the areas [illegible]

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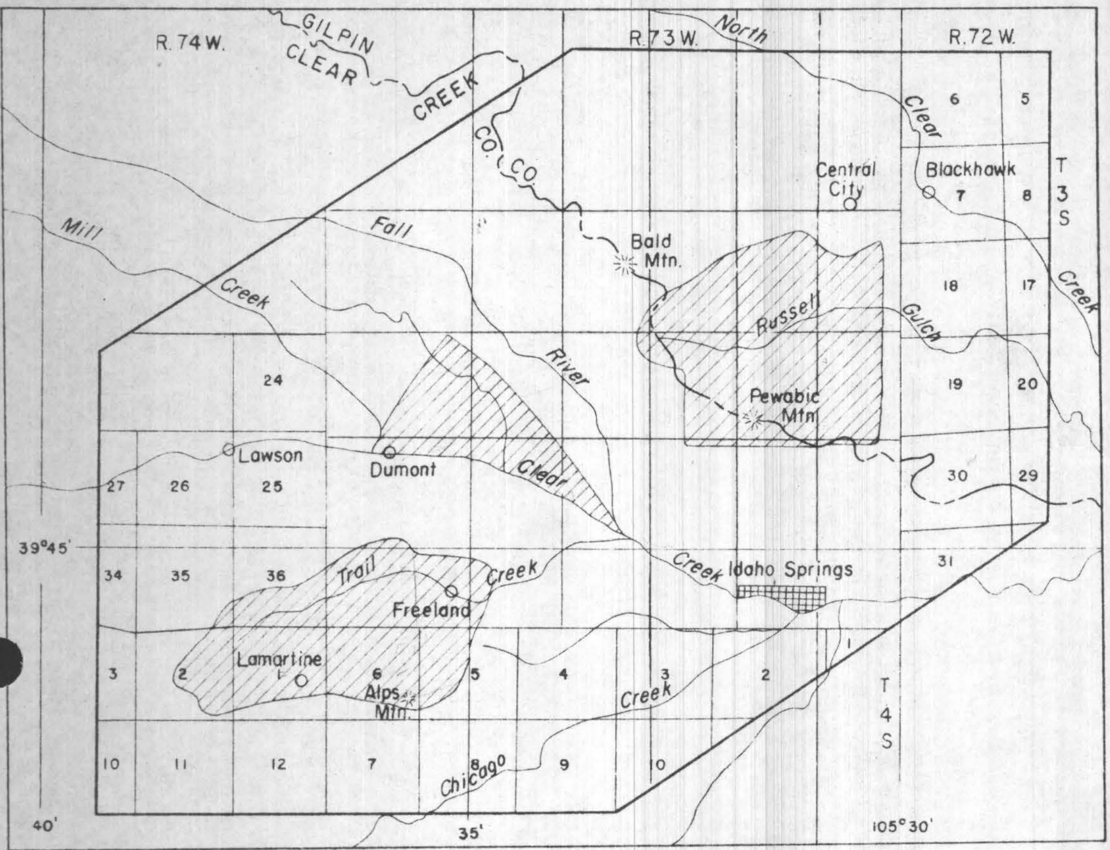

MAP SHOWING OUTLINE OF THE GEORGETOWN - CENTRAL CITY AREA,
COLORADO FRONT RANGE

Area mapped July - November 1952

fig 4

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Dumont-Fall River region, and Freeland-Lamartine district and radiometric reconnaissance was done in north-central Clear Creek County. In the Quartz Hill area of the Central City district, detailed mapping and sampling was done in the East Calhoun mine, a DMEA exploration project. A brief summary of each of the mapped areas and of the results of radiometric reconnaissance follows.

<u>Freeland-Lamartine district, Clear Creek County</u>, by J. E. Harrison

The field study of the Freeland-Lamartine district (fig. 4), an area of about 4 square miles, was completed in October. The area is underlain predominantly by igneous rocks, some of which have been metamorphosed, and complexly folded metasedimentary rocks of pre-Cambrian age. These rocks are cut by bostonite, quartz bostonite, and monzonite dikes and plugs of Tertiary age. The pre-Cambrian rocks are complexly folded into a series of upright and slightly overturned synclines and anticlines that trend about N. 30° E. and plunge gently northeast or southwest. Fracturing of this complex during Tertiary time formed a fault system that now contains the intrusive porphyry dikes and plugs and younger pyritic gold-copper-uranium-silver-lead-zinc-bearing veins.

The veins in the Freeland-Lamartine district are of the mesothermal type. Primary ore minerals include auriferous pyrite, free gold, chalcopyrite, argentiferous galena, tetrahedrite, and sphalerite. Secondary ore minerals include chalcocite, torbernite, autunite, and uranophane. In general, two stages of hypogene mineralization can be recognized. The early stage was principally auriferous pyrite with some chalcopyrite in a quartz gangue; the late stage was pyrite, chalcopyrite, galena, tetrahedrite, and sphalerite with both quartz and carbonate gangue. Local variations in mineralogy complicate this simple pattern, and hematite, fluorite, wulfenite, siderite, rhodochrosite, and barite are abundant in some of the veins.

Three vein systems can be recognized in the district. Although local variations can be found, in general the N. 30° E. system is strongly mineralized, the N. 60° E. system is somewhat less strongly mineralized, and the east-west system is weakly mineralized. Most of the veins on all three systems dip steeply to the north.

The radiometric examination of the district disclosed that a third of the mine dumps show abnormal radioactivity. The radioactivity, so far as known, is the result of secondary uranium minerals--torbernite, autunite, and uranophane--and radioactive limonite; no primary uranium minerals have been identified.

Broad regional mineral zoning is present in the mapped area. In general, three zones can be recognized: (1) a relatively high-temperature "core" of pyritic-gold veins, (2) a transition zone of pyritic veins which have been fractured and now have silver, lead, and zinc minerals in the fractures, and (3) an outer relatively low-temperature zone containing principally silver, lead, and zinc minerals. The mapped area contains veins that are principally of the transition and outer zone types. In general, the anomalous radioactivity appears to favor the outer side of the transition zone. This favorable area extends southward from the Freeland-Lamartine district into the mining districts along Ute and Cascade

Creeks, tributaries of Chicago Creek.

<u>Dumont-Fall River region, Clear Creek County</u>, by F. B. Moore

An area of about 1.5 square miles between Clear Creek and Fall River was mapped (scale 1:6,000) during the past field season. This area contains the Golden Calf mine, a potential source of pitchblende ore, and other radioactive occurrences. It lies between the Lawson-Dumont mining district and the Fall River region, which was examined for radioactivity by the Commission during 1951.

The bedrock in the mapped area is largely pre-Cambrian in age and consists principally of gneiss and schist of the Idaho Springs formation, together with monzonite gneiss, granite gneiss, and Silver Plume granite. The pre-Cambrian rocks are intruded locally by dikes of monzonite, quartz monzonite, and syenitic bostonite of Tertiary age. The pre-Cambrian rocks are folded into a series of anticlines and synclines that trend and plunge about N. 30° E. These folds are nearly isoclinal at many places. Northwest-trending faults of early Tertiary age cut and displace the porphyries; these faults are older than the generally eastward-trending faults that contain the veins. It is expected that further work will disclose many of the relations between faulting, porphyry emplacement, and vein formation in the region.

The veins in the mapped area principally belong to the pyritic gold type. One vein, at the Golden Calf mine near Dumont, is a potential source of uranium. Radioactive material was discovered in the ore bin, and later the mine was unwatered by the Survey and examined. The examination showed the presence of a generally strong radioactive zone along the vein for a horizontal distance of at least 60 feet and a vertical distance of 50 feet. Later this year the mine, together with others in the region that show abnormal radioactivity, will be mapped and sampled.

Central City district, Gilpin County, by P. K. Sims, A. A. Drake, and R. H. Moench

During the past six-month period about 3 square miles in the Quartz Hill and Russell Gulch areas were mapped (scale 1:6,000), and a project of detailed mapping and sampling was carried on in the East Calhoun mine. The Wood vein at the East Calhoun mine is being explored for uranium by funds supplied by DMEA.

The rocks in the mapped area are largely of pre-Cambrian age and consist principally of granite gneiss of variable lithology and metasedimentary rocks that have been included heretofore principally in the Idaho Springs formation. Porphyry intrusions of early Tertiary age--quartz monzonite, syenitic bostonite, quartz bostonite, and non-porphyritic quartz bostonite--cut the pre-Cambrian rocks. The porphyry intrusives were emplaced as dikes and small plugs and many can be traced for several thousand feet.

The principal fold in the mapped area is a northeast-trending anticline that crosses Quartz Hill. A complementary, sub-parallel syncline, lies 3,000 feet to the southeast. The broad fold pattern is complicated by drag and minor folds parallel to the major folds, and cross warps. The dips of the foliation are moderate to gentle, except locally; the lineation for the most part is parallel to the major fold axes, but locally plunges southeast or northwest, parallel to the cross faults. The joint pattern is complex.

Pitchblende is known to be present in the following mines in the Quartz Hill area of the Central City district--Kirk, Wood, Calhoun, Alps, Bezant, German, Belcher, Mitchell, Scandia, Harsh, Gold Ring, and Telegraph--and it has been reported from the Iron, Pewabic, and Gold Rock mines in Russell Gulch. Recent discoveries of pitchblende have been made at the Old Town mine, in Russell Gulch, at the Spread Eagle mine, in the southeastern part of the district, and at a mine in Eureka Gulch, 2 miles west of Central City. The radioactivity at the Spread Eagle mine and at the mine in Eureka Gulch was detected by prospectors.

The pitchblende deposits known in the Central City district occur in the transitional zone between a core of pyritic gold deposits and peripheral silver-lead-zinc deposits (Leonard, TEI-270). Also they are related spatially to quartz bostonite intrusive rocks (Phair, TEI-247). The character, size, and structure of individual deposits is little known because of the inaccessibility of the mines, but a few mines have been examined in part by earlier investigators; others will be investigated as the old mines are reopened and operated. During this six-month period, the pitchblende occurrences in the Old Town mine were mapped in detail. The pitchblende is restricted to the 6 and 7 levels, where it occurs in widely-spaced, small fractures between two gently-dipping veins--the Old Town and Wautaga. The uranium of the samples taken is far out of equilibrium and radium accounts for most of the radioactivity. The uranium has been leached by high sulfate waters that have moved through the mine, which is drained by the Argo tunnel.

Radiometric reconnaissance of north-central Clear Creek County, by J. D. Wells

Between June 15 and August 15, systematic radiometric reconnaissance was carried out in the Freeland-Lamartine, Chicago Creek, and Dumont-Fall River region. Three hundred and eleven mine dumps or workings were examined with a scintillometer and a Geiger counter.

Of the 311 localities examined, 71 (22.8 percent) were found to have abnormal radioactivity (radioactivity that cannot be accounted for by the wall rocks), 35 (11.3 percent) have significant anomalous radioactivity (two times background or more), and 5 (1.6 percent) have high anomalous radioactivity.

The source of the radioactivity on most of the dumps that were examined is limonite. Uranium minerals were identified, however, at 5 mines--the Golden Calf, Martha E, Muscovite, Miller, and Ariadne. Seventeen percent of the abnormally radioactive localities are associated with pyritic gold veins; 83 percent are associated with composite and silver-lead-zinc veins.

Summary of economic geology and plans, Colorado Front Range project

The discovery of three new radioactive localities in the Central City district makes it probable that additional new discoveries will be made in this region even though the district has been prospected rather thoroughly. The discovery at the Old Town mine is significant in that there is no radioactive material on the dump; also the pitchblende occurs at a depth considerably greater than it has been reported from the mines on Quartz Hill.

The discovery of abnormally radioactive deposits in parts of north-central Clear Creek County not known previously to contain uranium, considerably extends the area favorable for commercial pitchblende deposits. An economic evaluation of weakly radioactive dumps and veins cannot be made, however, until the geologic significance of their distribution is known, and this is dependent upon a knowledge of the regional geology. Continued detailed mapping of both the surface and underground should provide eventually the information not only as to why deposits of uranium are where they are, but also should allow adequate evaluation of areas that apparently contain only a few showings of secondary minerals and an unusual amount of abnormal radioactivity.

The information now available suggests that the pitchblende deposits can be related to hypogene mineral zoning (Leonard, TEI-270), the distribution of bostonite intrusives (Phair, TEI-247), and possibly to large, cymoid vein structures (Harrison, manuscript in preparation). The investigations in the Freeland-Lamartine district indicate that in this area abnormal radioactivity is restricted principally to a single vein of a group of parallel veins.

Because so few of the mines are or have been accessible, little is known yet concerning the general character, size, and structure of the known pitchblende deposits. This information cannot be obtained until more of the mines that contain pitchblende-bearing veins are reopened and until the veins are explored.

Field work has been recessed in the Freeland-Lamartine district. Mine mapping still is in progress in the Central City district and Dumont-Fall River region. During the next report period we will continue the detailed work on the Wood vein in the East Calhoun mine and will follow closely any new development work on pitchblende-bearing veins. Also, in addition to the map compilation and summation of field notes, we will make intensive petrographic studies of the rock and ore specimens collected during field work. These studies will provide fundamental geologic information that will materially aid in the geologic interpretation of the district. Geologic reports will be prepared on the Freeland-Lamartine district and the Albro mining area in the Dumont-Fall River region. A report on the detailed mapping and sampling of the Wood vein in the East Calhoun mine will be prepared at the finish of the exploration.

Mineralogic, geochemical and petrolgic studies
by George Phair and Norman Herz

The search for centers of intrusion of radioactive porphyry in the middle and northern parts of the Front Range Mineral Belt was continued during the field season of 1952 in the course of which some 162 samples of porphyry were analyzed for uranium and equivalent uranium by the Denver Trace Elements Laboratory. Because dikes of like composition tend to occur in clusters, it is possible to outline separate centers of intrusion. Centers of abnormally radioactive intrusion have been found in the Idaho Springs, Apex, and Gold Hill districts. None of these radioactive areas are comparable in extent or in degree of uranium enrichment to the very highly radioactive western half of the Central City district previously studied in detail. Outside of the clusters scattered dikes of similar composition are found. Such dikes in the Rollensville and Jamestown districts have been found to show at least some enrichment in uranium and in equivalent uranium over the regional average. Of the districts covered by the reconnaissance, and these include nearly all districts in the middle and northern parts of the mineral belt, only the complexly intruded Sunset-Ward district has been found to lack radioactive intrusions.

Certain generalizations previously found to apply to the Central City district (TEI-247) have been found valid for the larger area of the middle and northern parts of the mineral belt:

(1) Almost without exception the abnormally uranium and thorium-rich porphyries are rocks mapped as bostonite. Much thin section work remains to be done before we can say whether any of these radioactive bostonites are the quartz-rich variety found to be very highly radioactive in the Central City district. Not all bostonites are exceptionally radioactive and at least some of these less radioactive types belong to the quartz-poor variety (trachyte, syenite, bostonite) believed to represent a phase of alkali syenite.

(2) The late stage differentiates, alkali-rich quartz monzonite, bostonite, and syenite average at least three times as high in uranium and equivalent uranium as the Tertiary diabase and gabbros from the same small area.

(3) Where dikes and small stocks of similar composition occur in the same small area the dikes are more highly enriched in uranium and thorium than are the stocks. The difference is even more marked on a regional

scale when separate areas characterized by dike swarms are compared with those of stocks. This evidence accords with evidence from the Central City district and elsewhere in the Front Range to the effect that the dikes served as flues and channelways facilitating the escape of volatiles and solutions from larger bodies cooling at depth.

Thin sections of quartz bostonite from the Central City district covered with alpha-sensitive stripping film were exposed for 5 months and are now under study. Preliminary results confirm our previous opinion (TEI-247) that much of the radioactivity in these rocks is concentrated in zircon. The zircon is the brown, translucent, completely metamict variety and was first pointed out to us in these thin-sections by Prof. E. S. Larsen. As was suspected, some of the radioactivity is also present in disseminations of iron oxide which may or may not be supergene.

Now in various stages of preparation are the following papers: (1) preliminary report (with P. K. Sims) on the Copper King, zinc-pitchblende mine, Prairie Divide district, Larimer County, Colo.; and (2) a summary and evaluation (with Kiyoko Shimamoto and P. K. Sims) of the results of recent age determinations in the Front Range including 7 new determinations by ourselves.

During the past half year our paper on "Radioactive Tertiary Intrusives in the Central City District" was issued as TEI-247 and a brief summary of it was given in a 20-minute talk at a meeting of the Geological Society of Washington. Publication in Economic Geology is planned. A paper entitled "Hydrothermal Uranothorite in Fluorite Breccias from the

Blue Jay mine, Jamestown, Colorado", (TEI-144 by Phair and Shimmamoto) was published in the July-August issue of the American Mineralogist. A paper entitled "Notes on the differential leaching of uranium, radium and lead from pitchblende is H_2SO_4 solutions" by Phair and Levine was issued as TEI-262 and formed the basis of a talk on the same subject given at the Boston meeting of the Geological Society of America. Publication of this paper in Economic Geology is planned.

Thomas Range fluorite district, Juab County, Utah
by M. H. Staatz and F. W. Osterwald

The Thomas Range fluorite district is in Juab County, about 50 miles northwest of Delta, in the western part of the Thomas Range. Within an area 6 miles long and 2-1/2 miles wide, uraniferous fluorite pipes cut dolomites of Ordovician and Silurian age. The dolomites are underlain by Ordovician quartzite, shale, and limestone, and overlain by Silurian or Devonian limestone. The Paleozoic sedimentary rocks trend north-northeast to northeast, and dip 20° to 60° northwest, but they are complexly faulted, and individual beds are repeated many times. Tertiary (?) rhyolites, tuffs, agglomerates, and basalts underlie large areas in the eastern and southern parts of the district. Rhyolite plugs and masses of intrusive breccia locally intrude the sediments.

The district has produced 68,888 short tons of fluorspar since 1943, and 5 mines--the Bell Hill, Lucky Louie, Lost Sheep, Blowout, and Flurein Queen--are currently producing from pipe-like ore bodies. In addition to the pipes, there are several fluorite veins that cut dolomite at many places, but most of the veins are very small, and only one has yielded fluorspar. The rhyolite contains small vugs and minute veinlets of purple and colorless fluorite at a few localities. Light yellow tuff contains disseminated clots and masses of fine-grained purple fluorite at two places along the western edge of the district. Fluorspar pipes are located: (1) along faults or in broken zones near faults, (2) near Tertiary intrusives, or (3) in complexly faulted areas. The total fluorspar reserves of the district are estimated at about 290,000 tons.

Most of the Thomas Range fluorite is radioactive, and assays indicate a uranium content ranging from 0.006 to 0.330 percent. The highest uranium assays are from the southern part of the district, particularly from the Bell Hill mine. The assay data from the Bell Hill mine indicates a sharp decrease in average grade as depth increases (fig. 5). Final analysis and evaluation of this trend must await uranium analyses from 53 samples collected in November. Spectrographic and chemical analyses of fluorine and other metallic elements besides uranium is being carried out to determine whether there is a general depth zoning within individual ore pipes.

The final report on the district, "Geology of the uraniferous fluorspar pipes, Thomas Range, Juab County, Utah", by M. H. Staatz and F. W. Osterwald is now being prepared. It will include a map of the district at a scale of 1 inch to 500 feet, and detailed maps of the more important deposits. The report will present new data on the stratigraphy and structure of the district, additional information on the petrology of the rocks associated with the uraniferous fluorspar pipes, and a detailed description of the uraniferous fluorspar ores.

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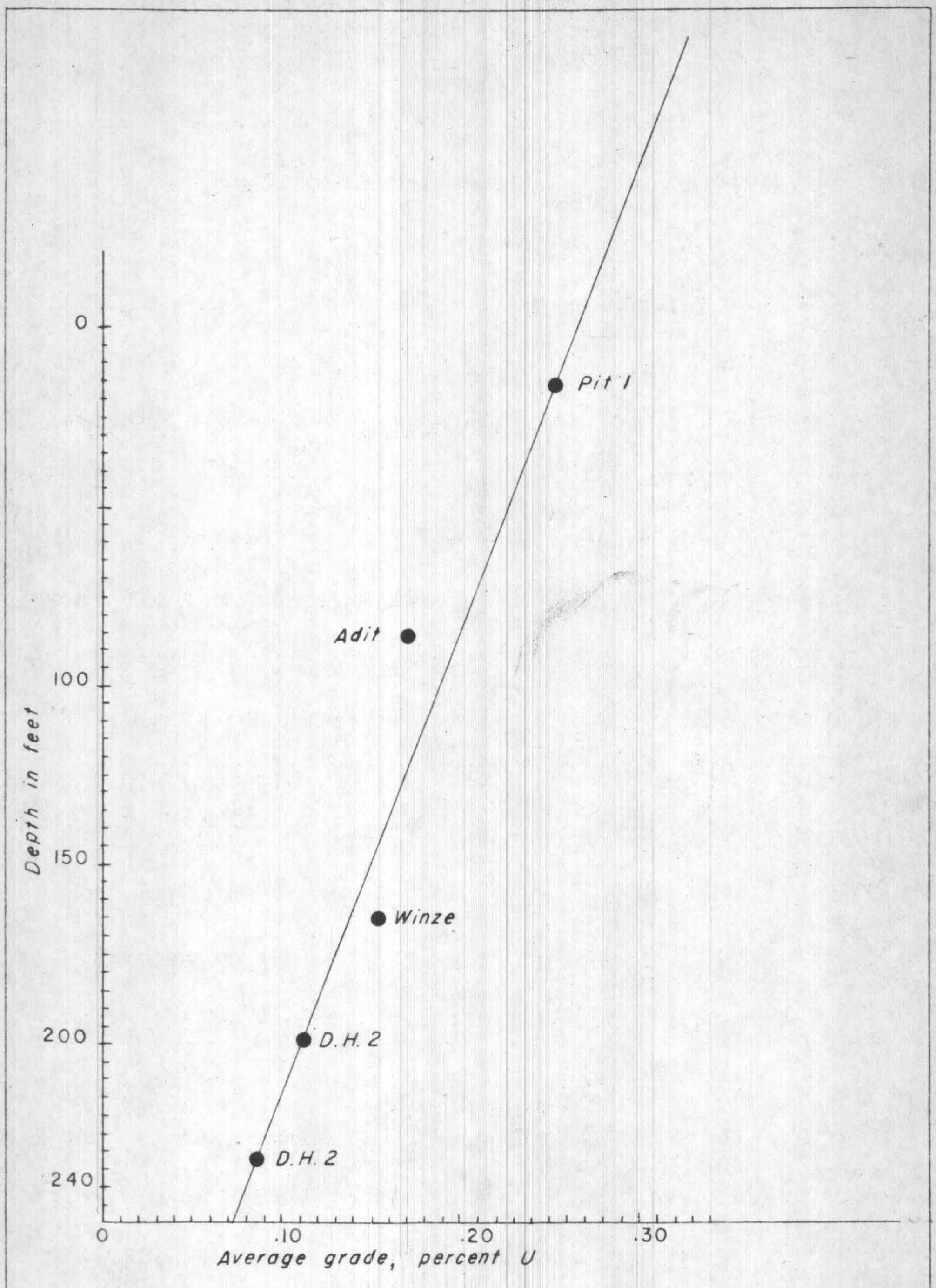

DEPTH-GRADE RELATIONSHIPS, BELL HILL MINE, THOMAS RANGE FLUORITE DISTRICT, UTAH.

fig 5

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Boulder batholith, Montana
by G. E. Becraft

The objectives of the study of the Boulder batholith district, Mont., are: (1) to make a geologic map of those areas within the batholith containing known anomalous radioactivity, (2) to extend the geologic mapping within the batholith to adjoining areas with similar structures, veins, and altered zones that suggest possible additional anomalous radioactivity, (3) to study the alteration surrounding uranium deposits and deposits containing no uranium in order to determine guides to ore, (4) to make a petrologic study of the rocks within the area containing anomalous radioactivity, and (5) to prospect all veins and altered zones for anomalous radioactivity.

During this 6-month period, about 10 square miles was mapped in the southwestern corner of the Comet area and about 40 square miles northwest of Jefferson City, Mont.

In the Comet area, two moderate radioactivity anomalies--the Uncle Sam and Hattie Ferguson mines--and four weak radioactivity anomalies were found. Analytical data on samples are not yet available. However several radioactivity anomalies and a few specimens of sooty pitchblende and other uranium minerals have been found on the mine dumps of formerly productive base- and precious-metal mines along the Comet-Gray Eagle shear zone in the Comet area in southwestern Montana. The shear zone is from 50 to 200 feet wide and has been traced for at least $5\frac{1}{2}$ miles. It trends N. 80° W. across the northern part of the area and cuts the quartz monzonitic rocks of the Boulder batholith and younger silicic intrusive rocks, as well as the pre-batholitic volcanic rocks, and is in turn cut by dacite and andesite dikes.

The youngest period of mineralization is represented by chalcedonic vein zones comprising one or more discontinuous stringers and veins of cryptocrystalline silica in silicified quartz monzonite and in alaskite that has not been appreciably silicified. In some places these zones contain no distinct chalcedonic veins, but are represented only by silicified quartz monzonite. These zones locally contain uranium in association with very small amounts of the following minerals: pyrite, galena, ruby silver, argentite, native silver, molybdenite, chalcopyrite, arsenopyrite, and barite. At the Free Enterprise mine, uranium has been produced from a narrow chalcedonic vein that contains disseminated secondary uranium minerals and local small pods of pitchblende and from disseminated secondary uranium minerals in the adjacent quartz monzonite.

Undiscovered commercial deposits of uranium ore may occur spatially associated with the base- and precious-metal deposits along the Comet-Gray Eagle shear zone, and chalcedonic vein zones similar to the Free Enterprise.

In the area northwest of Jefferson City, two moderate and six weak radioactivity anomalies were detected along chalcedonic vein zones. Computation of reserves will be made when analytical data are available. There is a suggestion of a pattern formed by the areal distribution of the uranium deposition associated with the chalcedonic vein zones ("reefs"). The uranium minerals appear to be centered in an area of a few square miles west and southwest of Clancey. Outward from this area, although the vein zones are common, radioactivity anomalies become less common. However, until detailed areal mapping is done east of Clancey and north of Lump Gulch, about one mile north of Clancey, this pattern cannot be definitely demonstrated. If this pattern, which is now merely a suggestion, is true, there is a good possibility of additional uranium deposits north of Lump Gulch and a slight possibility of deposits east of Clancey.

During the next six months period, laboratory studies on rock alteration, rock types, and ores will be made and a report will be prepared.

White Signal-Black Hawk districts, Grant County, New Mexico
by Elliot Gillerman

During the six months period covered by this report, work was completed in the Black Hawk district and a final report is being prepared containing the results of the study and a recommendation for physical exploration. Geologic mapping was resumed in the White Signal district and to date about 9 square miles have been mapped. The results, conclusions, and future plans for each of the districts will be discussed separately.

Black Hawk district

Geologic mapping in the Black Hawk district was completed just prior to the start of the current six-month period. Detailed studies of one of the deposits, the preparation of the report, and the logging of three 1,000-foot diamond drill holes was the extent of the work during the past six months. The drilling was done under a DMEA loan and was completed in November 1952.

The results of the work done in the Black Hawk district are being set forth in a report entitled "The uranium-bearing nickel-cobalt-native silver deposits in the Black Hawk district, Grant County, New Mexico" by Elliot Gillerman and Donald H. Whitebread.

In brief, the report presents the regional geology of an area of about two and one-half square miles within which are the major ore deposits of the district. A pre-Cambrian quartz diorite gneiss, which contains inclusions of meta-sedimentary and meta-igneous rocks, is the predominant rock type in the district. The gneissic structure is primary and is not reflected in the included rocks. Numerous pre-Cambrian and younger rocks intrude the gneiss as dikes, small stocks, and irregular masses. Monzonite porphyry is the chief of these younger rocks and occurs as a small stock along the northwest edge of the district and as numerous dikes and small masses. Beartooth quartzite of Cretaceous age overlies the pre-Cambrian rocks northeast of the district.

The ore deposits are fissure veins of the nickel-cobalt-native silver ore type, and contain pitchblende. They are similar mineralogically to the deposits at Joachimstahl, C$_z$eckoslovakia, Great Bear Lake, Canada, and Cornwall, England. The ore minerals include pitchblende, native silver, argentite, niccolite, skutterudite, and nickel skutterudite. The principal gangue minerals are calcite, dolomite, siderite, quartz, and barite. The veins trend mostly northeast and dip steeply to the northwest, they parallel the old pre-Cambrian structure. Radioactivity was noted at ten separate localities, all of which lie within a belt, 1,000 to 3,000 feet wide, extending from near the southwest corner of the mapped area to the northeastern edge of the district. This belt parallels the southeastern boundary of the monzonite porphyry stock. All of the major ore deposits are along faults in the gneiss in close proximity to where these faults cut dikes or irregular masses of the monzonite porphyry.

No further work is planned in the district except the microscopic studies of the rocks and the ore minerals if and when a suite of these minerals can be obtained.

White Signal district

The objectives of studying the White Signal district are: (1) to find minable deposits of uranium, (2) to appraise the resources of uranium in the district so that potential production of the area can be established, and (3) to determine the nature and origin of the deposits, not only as a guide in the search for uranium in the White Signal district, but also to aid in the search for uranium in other areas. To achieve these objectives a radiometric survey of the district, detail mapping of individual properties, and regional mapping of about 60 square miles within which the deposits occur, is necessary.

The radiometric survey of the district was completed prior to the start of the six-months period covered by this report, and more than 75 separate localities spread over an area of about sixty square miles, were found to contain radioactive material. The greatest concentration of these was within an area of about 6 to 7 square miles in the immediate vicinity of

White Signal. The exposed portions of the deposits are small, but little information is available as to actual dimensions. The uranium occurs as the secondary minerals autunite and torbernite and analyses of some of the deposits show as much as 0.2 percent U_3O_8 over widths of five feet.

During the past six months areal mapping was started in the area of concentrated uranium mineralization. About 7 square miles have been mapped, which together with about 2 square miles of adjoining territory mapped previously, makes a total of about 9 square miles. This 9 square miles covers most of the area of concentrated uranium mineralization.

Future plans consist of continued areal mapping and detailed studies of the deposits. Additional mapping is needed before an understanding of the complete regional setting can be secured. Only after this regional picture is obtained can the uranium mineralization be fitted into its proper setting, and the origin, paragenesis, and localization of the uranium be understood. During the coming six months detailed studies of five or six of the more important deposits will be made, and the regional mapping will be extended. Underground studies, which should be made of some of the deposits, may be done during the coming six months if time allows.

Adjoining the White Signal district on the north is the Tyrone copper district. The Phelps Dodge Corporation has sunk over 120 churn drill holes within the past four years to test this area for copper. Some of these holes are within a mile or two of known uranium deposits in the White Signal district. Arrangements have recently been completed with the Phelps Dodge Corporation and with the Radiometric Logging Unit of the

Geological Survey to check these drill holes for radioactivity by means of gamma-ray logging. This work is scheduled to be done in December 1952.

Placerville area, San Miguel County, Colorado
by V. R. Wilmarth

In the Placerville area, eastern San Miguel County, uranium minerals are known to occur in bedded deposits in the Entrada sandstone of Jurassic age and in vein deposits in the Dolores formation of Triassic and Jurassic (?) age. July, August, September, and part of October of 1952, were spent in mapping the topography and geology of approximately 2.5 square miles (scale one inch equals 500 feet) in the central part of the Placerville area. The primary purposes of this investigation were: (1) to obtain data on the relationship of hydrocarbon, both radioactive and non-radioactive, to the base metal sulfide vein deposits and to the bedded uranium-vanadium-chromium deposits; and (2) to determine the reserves of uranium and base metals in the vein deposits. Radiometric examination and detailed sampling of the vein deposits has been completed.

The geologic formations in the mapped area are conformable and, from oldest to youngest, consist of the Cutler formation of Permian age; the Dolores formation of Triassic and Jurassic (?) age, the Entrada sandstone and Wanakah formation of Jurassic age, and the Morrison formation and Dakota sandstone of Cretaceous age. The nearly horizontal sedimentary rocks have been complexly faulted and intruded by an andesite porphyry dike of Tertiary age. Approximately a mile east of the mapped area, three small diorite stocks and numerous dikes of diorite and monzonite porphyry intrude the sedimentary rocks.

Within the mapped area, two fault systems are recognized. The more pronounced system is comprised of the west-trending, steeply dipping normal faults, that approximately parallel the strike of the beds. The other system is shown best in the eastern part of the mapped area; there the faults trend north-northwest, dip steeply, and cut off the west-trending faults. Most faults in the area are normal and the displacements are generally less than 100 feet although a few have displacements of nearly 500 feet. Vein deposits that contain base metal sulfides and uranium minerals are known only along the west-trending faults; mineralization on the north-northwest-trending faults consists primarily of calcite veins.

Ore deposits in the mapped area consist of uranium-vanadium-chromium deposits of sedimentary origin in the Entrada sandstone, and vein deposits of hydrothermal origin in the pre-Entrada sedimentary rocks. The deposits in the Entrada sandstone have been described in detail by Fischer (1947) and other than a close spatial relation, no evidence was found that the bedded uranium deposits are related genetically to the vein deposits. The vein deposits that contain uraniferous hydrocarbons at the Weatherly and Robinson properties have been briefly described by Wilmarth (1951).

During the field work two new occurrences of radioactive material were discovered near the Weatherly property in the western part of the mapped area. At both localities, the radioactive material is hydrocarbon, and megascopically is similar to the uranium-bearing hydrocarbon at the

Weatherly and Robinson properties. In one area the hydrocarbon fills the center of calcite veins that are, as much as one inch thick, in a 4 to 6 inch shear zone in the Cutler formation. At the other occurrence black, vitreous, highly radioactive hydrocarbon occurs in a 6 to 8-inch thick bed in an area of faulted Dolores formation. The bed can be traced along the strike for approximately 40 feet and is within 6 feet of a fault that contains copper minerals. The total inferred uranium reserves of these two occurrences is less than 2 tons of uranium-bearing rock that average 0.02 percent uranium.

The vein deposits in the Placerville area are of the mesothermal type. The predominant primary ore minerals are tetrahedrite, tennantite, and chalcopyrite with minor quantities of galena, sphalerite, and bornite in a gangue of calcite, barite, pyrite, and quartz. Secondary copper minerals--chalcocite, azurite, malachite, and chrysocolla--are abundant on the surface outcrops of the veins. In the Placerville area there appears to be a broad general zoning of the ore minerals in the vein deposits--gold-quartz-pyrite fissure veins occur in the intrusive stocks east of the mapped area; lead-silver vein and replacement deposits in the Pony Express limestone are within 2,500 feet of the stocks; and deposits that consist essentially of tetrahedrite, tennantite, and chalcopyrite in a gangue of calcite and barite are on the peripheries. The known occurrences of uranium-bearing hydrocarbon are restricted to the copper-rich zone.

In summary, the results of this field season indicate that (1) the largest uranium reserves in the Placerville area are in the bedded deposits in the Entrada sandstone, (2) uranium reserves of uranium-bearing hydrocarbon are only slightly larger than previously thought, (3) the known uraniferous hydrocarbons are associated with primary copper minerals, in or near faults; and (4) although the bedded uranium deposits and the uranium-bearing vein deposits are closely related spatially, there is no evidence that these two types of deposits are related genetically.

A report on the ore deposits of the mapped area will be completed this winter.

Garo, Colorado
by V. R. Wilmarth

The objectives of this project are to (1) determine the horizontal and vertical extent of the uranium-vanadium-copper mineralization in the Maroon formation of Permian age, (2) obtain data that would aid in prospecting geologically similar uranium-vanadium-copper deposits and, (3) study the distribution of the uranium, vanadium and copper minerals in the deposit.

The Shirley May (Garo) uranium deposit consists primarily of tyuyamunite and carnotite as disseminations and fracture fillings in three sandstone beds in the Maroon formation. The deposit is on the northeast flank of the Garo anticline, a local structure related to Tertiary deformation. In the immediate vicinity of the deposit the Maroon formation has been cut by numerous northerly-trending faults that have horizontal displacements of as much as 1,000 feet. Tyuyamunite, carnotite, volborthite, calciovolborthite, malachite, azurite, covellite, chalcocite, chalcopyrite and several unidentified yellow to dark red vanadium minerals occur in the three fractured sandstone beds. The ore body that has yielded most of the uranium ore is in the uppermost ore-bearing sandstone bed that is stratigraphically 50 and 150 feet above the other ore horizons. The uranium content of samples from the mine ranges from 0.001 to 0.48 percent uranium. During June, July, and August 1952, this deposit was explored by diamond drilling.

The results of the diamond drilling as outlined in the joint report by V. R. Wilmarth of the Geological Survey and L. E. Smith of the Atomic Energy Commission are:

(1) A new sandstone bed was found that is a favorable host rock for uranium, vanadium, and copper ore bodies.

(2) Potential uranium ore bodies occur in the sandstone beds within a vertical distance of 120 feet below the surface.

(3) The area of known uranium mineralization is restricted to favorable parts of the sandstone beds within highly faulted areas.

(4) Small uranium ore bodies possibly occur in the three sandstone beds within the area explored and to the northwest and southeast of the mine, but cost of exploration and mining these bodies is not economical.

A final report on the geology of the Shirley May (Garo) deposit will be prepared this winter. This report will present detailed information concerning the mineralogy, petrology, and structure of the deposit.

Lost Creek schroeckingerite, Sweetwater County, Wyoming
by D. M. Sheridan

The objectives of field work at Lost Creek during the report period were: to obtain additional data for calculating tonnage and grade, and to obtain additional information on the controls and localization of schroeckingerite. In order to accomplish these objectives the Survey continued the exploration by means of trenching, mapped all trench walls (scale 1:120), mapped the exploration area (scales 1:2400 and 1:9600) and carried on an extensive sampling program.

The Lost Creek schroeckingerite deposit is principally in secs. 30 and 31, T. 26 N., R. 94 W., 6th principal meridian. At the present time the Survey does not know who the rightful owners are of the claims covering the main portion of the deposit; the claims of two groups of people are in conflict.

During the period, July-November 1952, seven new trenches, totalling approximately 10,300 feet, were excavated. The trenches were examined at night with ultra-violet lights to determine boundaries of individual schroeckingerite bodies. During daylight hours the trench walls were mapped (scale 1:120). Face-cut samples of all schroeckingerite deposits, channel samples of the host rock, samples of radioactive rock other than schroeckingerite-bearing material, and representative petrographic samples were obtained from the trenches.

Approximately 4 square miles were mapped by plane table (scale 1:2400) in the main exploration areas. In addition, about 3 square miles were plane-tabled at a scale of 1:9600. A plane-table traverse was made to tie in the Lost Creek geology to the synclinal structure and the stratigraphic units being mapped by the Red Desert lignite project.

Schroeckingerite, a complex hydrated sulfate, carbonate, and fluoride of calcium, sodium, and uranium occurs in beds consisting of interfingering facies of the Wasatch and Green River formations of late Early Eocene age. These beds strike northwestward and dip about 20° NE in the immediate area of the deposit.

Two large schroeckingerite-bearing areas were indicated by the exploration: (1) the main area, at least 10,000 feet long and ranging in width from 100 feet to about 1,000 feet; and (2) a subsidiary area, at least 8,200 feet long and ranging in width from 50 feet to 600 feet. The main mineralized area occurs within the Cyclone Rim zone of faulting, which trends northwest for a distance of 12 to 15 miles and is about 1100 feet wide in the vicinity of the deposit. The mineralized portion of the zone of faulting is apparently limited on the west by Lost Creek and on the south by brown shale of the Green River type. The eastern limit of the main deposit is known to lie somewhere between the last two trenches (trenches 12 and 13), but the northern limit is not well defined; small schroeckingerite deposits were mapped in that part of trench 7 which connects the main area with the northern area but their small size and sparse distribution suggests that the area between the two deposits is relatively barren. The northern deposit is also apparently limited on the west by Lost Creek and narrows to 60 feet in trench 11 at the eastern extremity; the northern limit is not well defined.

Schroeckingerite was found in all of the trenches except trench 13 and the southern half of trench 8 (which lies west of Lost Creek). Two zones of abundant ferruginous-cemented sandstone fragments were found at the surface in the vicinity of trench 13. These zones of ferruginous float ore are about 3000 feet and 8000 feet long and are abnormally radioactive. It is believed that this ferruginous float may be the cause of the radioactive anomaly reported in this vicinity by airborne radiometric work conducted last summer by the Fuels Branch. The sandstone fragments form a well defined contact at the base of a brown shale unit (Green River); the two zones are repetition caused by a fault displacement.

Quaternary deposits cover much of the Lost Creek area so that the distribution of schroeckingerite deposits is known mainly from exploratory work.

The inferred reserves of uranium were presented in TEM-288, and are based on information obtained from trenches 1-6, which were mapped and sampled from December 1951 to January 1952. Calculations of tonnage and grade from data obtained in trenches 7-13, have not yet been made; a revised version of reserves will be reported in a final TEI report after all analytical work and computations have been completed.

Field work at Lost Creek was completed on November 22, 1952. It is believed that the field data are as complete as possible within the scope of the objectives of the Survey's exploration program. Therefore no further field work is planned at the Lost Creek deposit.

The office work will be directed toward a final report to cover both the geologic results and the economic results of all Survey exploration at the Lost Creek deposit.

Ralston Creek and Golden Gate Canyon areas, Jefferson County, Colorado
by John W. Adams and Ernest P. Beroni

Pitchblende, associated with base-metal sulfides, has been found at eight localities in the northern part of Jefferson County, Colo. All the deposits are in shear zones that cut pre-Cambrian metamorphic and igneous rocks, chiefly hornblende gneiss, biotite schist, and granite pegmatite. The location of the deposits are shown on figs. 6 and 7. Two of the pitchblende occurrences were found by a local prospector in 1949; the six other deposits were found by personnel of the Reconnaissance Group during 1951 and 1952.

Geologic work to date in the Ralston Creek and Golden Gate Canyon areas has been confined to limited studies of the individual deposits. Preliminary geologic maps of the immediate vicinity of two of the deposits have been completed, and geologic maps or sections (scale 1 inch equals 10 feet) have been made of the underground workings at five of the pitchblende occurrences.

The pitchblende deposits, with one exception, occur in shear zones that contain vein-like bodies of carbonate-rich breccia. The breccia bodies range from 1 to 5 feet in width and are related probably to the major Laramide faults, or "breccia reefs" of similar trend, mapped by Lovering and Goddard. The breccias are composed of fragments of

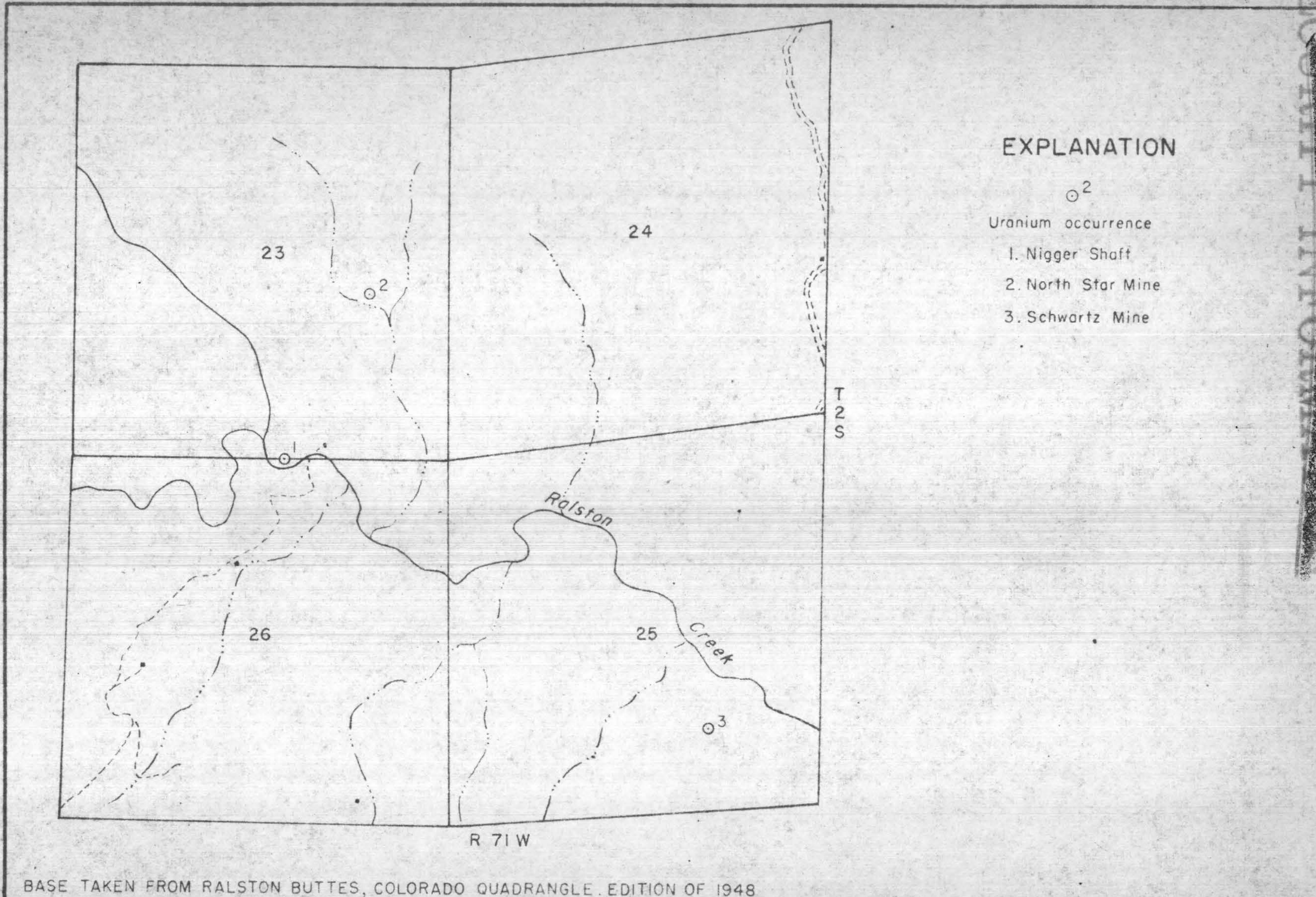
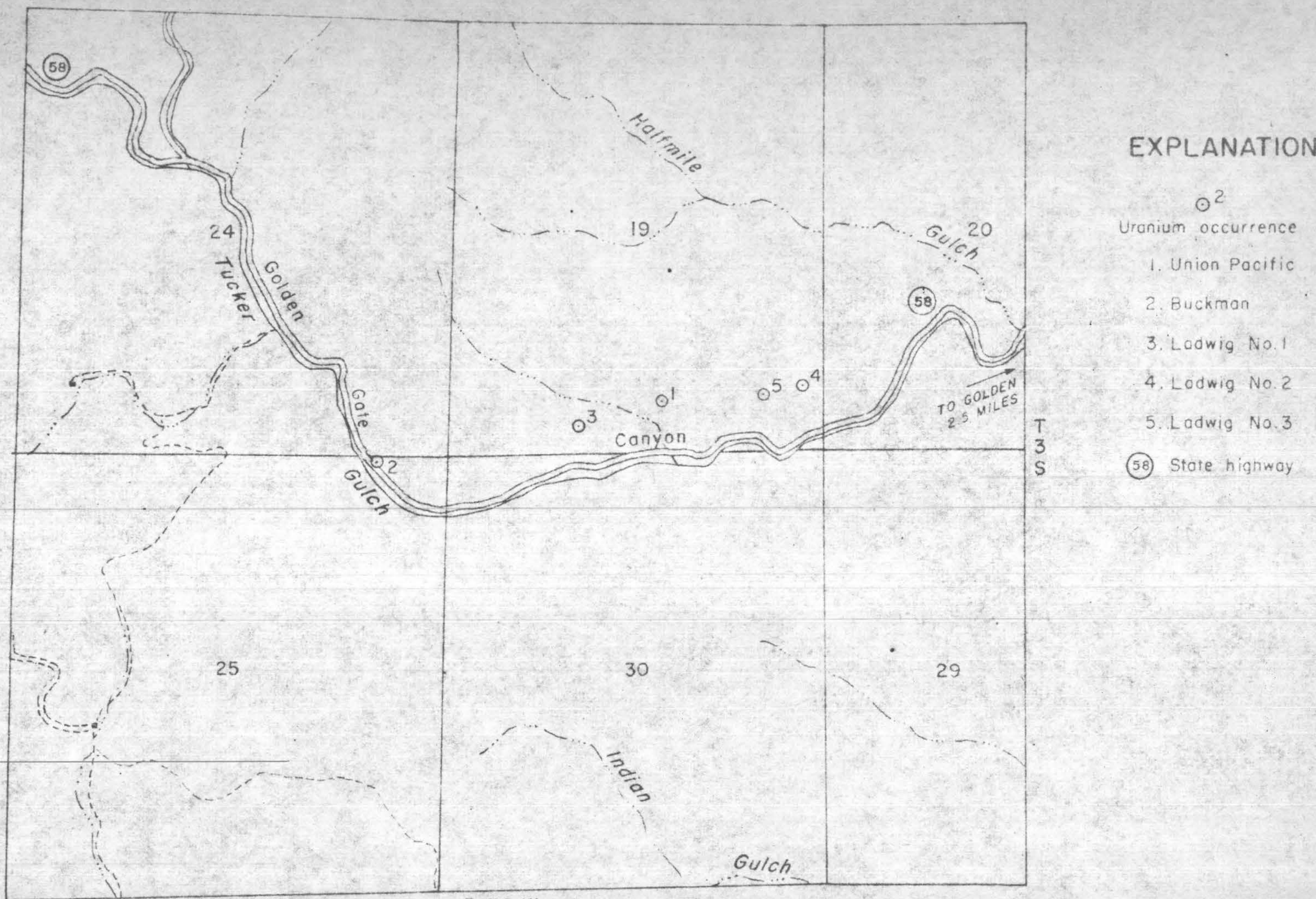


FIGURE 6 – INDEX MAP SHOWING KNOWN URANIUM OCCURRENCES IN THE RALSTON CREEK AREA, JEFFERSON COUNTY, COLORADO

1000 0 1000 5000 Feet

105



BASE TAKEN FROM RALSTON BUTTES, COLORADO, QUADRANGLE, EDITION OF 1948.

FIG. 7 — INDEX MAP SHOWING KNOWN URANIUM OCCURRENCES
IN GOLDEN GATE CANYON AREA, JEFFERSON COUNTY, COLORADO

1000 0 1000 5000 Feet

bleached and iron-stained wall rock, usually hornblende gneiss, that have been veined and cemented by carbonate minerals and orthoclase (?). Pitchblende and associated ore minerals, chiefly copper sulfides, occur in or along the margins of the breccias, and apparently were introduced at a late stage of carbonate mineralization. At one deposit, the pitchblende occurs in narrow shear zones not known to be related to any large breccia bodies.

All but one of the deposits had been prospected in the past, presumably for copper, but existing exposures are generally insufficient to determine the extent of the ore bodies. Because of this lack of information, no reserve estimates were made.

The potential of some of the deposits is large by virtue of the extent of the favorable breccia zones, and should warrant the complete exploration of those deposits that appear to offer the best combination of structure and mineralization. On the basis of present information, the deposits at the Schwartz mine and at the Union Pacific prospect seem to be the most promising.

Copper King mine, Prairie Divide district, Larimer County, Colorado
by P. K. Sims

A study of the copper King mine was undertaken in 1951 to determine the general character, size, and structure of the pitchblende deposit. This investigation has been largely completed and an interim report on the geology and ore deposits of the mine is in preparation. A brief summary of the report being prepared by P. K. Sims and George Phair follows.

The Copper King mine, in the northern part of the Colorado Front Range, was operated for a short time prior to World War II for copper and zinc, but since 1949, when pitchblende was discovered on the mine dump, it has been developed for uranium.

The bedrock in the mine area consists predominately of pre-Cambrian granite with minor migmatite and metasediments. Faults, confined to a narrow zone that extends through the mine, cut both the pre-Cambrian rocks and the contained massive sulfide deposits.

Two types of mineral deposits--massive sulfide and pitchblende deposits--in the mine are of widely different mineralogy, age, and origin. The massive sulfide deposits are small and consist of pyrite, sphalerite, chalcopyrite, pyrrhotite, and in places magnetite in amphibole skarn and related mica sköls and quartzite. The deposit at the Copper King mine has yielded a few tens of tons of high-grade sphalerite ore. The massive sulfides are pyrometasomatic deposits of pre-Cambrian age.

The pitchblende at the Copper King mine is principally in the Copper King vein, a tight, hard breccia zone, as much as a foot thick, that cuts through both granite and the massive sulfide deposit. A small part of the pitchblende is in small fractures near the vein, in boxwork pyrite adjacent to the vein, and in post-ore faults close to their intersection with the Copper King vein. In the lower part of the mine, in granite wall rocks, the vein branches and "horsetails". The pitchblende in the deposit forms a steeply-plunging ore shoot that has a horizontal length of more than 50 feet and a height of about 85 feet. The thickness of the ore shoot averages about two feet, but ranges from a feather edge to more than 4 feet. The pitchblende within the shoot forms discontinuous, generally small pods and lenses. The pitchblende is fine-grained and intimately intergrown with siderite; other gangue minerals include pyrite, quartz, and finely comminuted fragments of the wall rocks, including chalcopyrite. The vein was repeatedly reopened during mineral deposition as shown by several stages of brecciation and recementation by the vein matter. The pitchblende is early Tertiary in age and probably formed at intermediate temperatures and depths.

The Copper King mine has shipped about 51 tons of pitchblende ore that averaged more than 0.5 percent uranium. The reserve of indicated and inferred ore in the mine is estimated to be about 550 tons that contains on the average 0.5 percent uranium. This ore is within the pitchblende ore shoot that has been more or less outlined by mining. The recent core drilling by the Commission probably has increased slightly the total inferred ore reserve.

During the next report period, laboratory studies of the ore and wall rocks will be carried on largely by G. Phair. Additional detailed studies of the deposit will be made as mining progresses.

SEARCH FOR AND GEOLOGY OF URANIUM IN CARBONACEOUS ROCKS

Reconnaissance

Eastern States
by S. W. Welch and J. W. Huddle

The Eastern Coal Reconnaissance project was undertaken to search for traces of uranium in commercially mined coals. Previous work showed that there is very little uranium present in eastern coals but the present project was started in the hope of finding uranium in quantities large enough to be concentrated in the ash to 0.05 percent or more by burning the coal in large industrial plants.

Field work was started in August 1952 and continued until November 26, 1952. S. W. Welch, J. L. Snider, J. W. Huddle, J. E. Johnston and W. E. Todd Brown participated in the field work. The field work undertaken consisted of collecting coal samples and measuring the radioactivity of stratigraphic sections with a Geiger counter or scintillometer. Coals were sampled and sections measured in Indiana, Illinois, western Kentucky, Ohio, Pennsylvania, West Virginia, eastern Kentucky and Tennessee.

In most instances channel samples were cut through the coal bed in commercial mines which produce more than 250,000 tons of coal per year. A single sample was cut at more localities but at other places three or more samples were taken from the bed. In these places it seemed possible that coal from the segments represented by the samples could be kept separate or there was some reason to believe that there might be differences in the radioactivity of various parts of the bed. The coal samples taken were crushed in a jaw crusher and tested in the field or office for radioactivity with a Berkeley Geiger counter equipped with an assay cup. In the early part of the work one-minute background readings were taken, a coal sample reading was then taken and it was followed by another background reading. Early in November the counters were standardized by use of a standard sample in a range 0.02 percent eU. Readings subsequent to this time were more nearly comparable to each other and can be converted to microroentgens or eU. The conversion to standard units will be done after laboratory analyses of coal submitted to the Trace Elements Washington Laboratory are available for checking the validity of our radiometrics. To date no laboratory analyses are available.

Coal samples from 20 localities have shown a radioactivity in excess of background. These samples probably range from less than 0.001 to 0.002 percent equivalent uranium if the field counters have been calibrated correctly. The following list gives the location and relative radioactivity for each of these 20 samples.

Locality and coal	Sample Reading / Background Reading
1. Better Coal Co. truck mine about 5 miles west of Middlesboro on U. S. Highway 74, Bell Co., Ky. Mason (?) coal - 30" coal; 2 1/2" shale parting.	(60/39.5 = 1.6)
2. Pruden Coal Co. rail mine near Pruden, Claiborne Co., Tenn. Rich Mtn. coal - 33" coal; 2" shale parting.	(58/34.5 = 1.7)
3. Mary Helen Coal Corp. rail mine about 7 miles SE of Harlan, Harlan Co., Ky. Low Splint coal - 52" coal; 1/2" shale parting.	(56/31 = 1.8)

Locality and coal (continued)	Sample Reading / Background Reading	
4. Domestic opening near Emmalena, Knott Co., Ky. Upper block of Haddix coal - 28 1/2" coal; 1/2", 1/4", 1", 1/2" shale partings	(70/47	= 1.5)
5. Abandoned truck mine on Highway 30 west of Jackson, Ky., just inside Breathitt Co. line. Fire Clay Rider (?), lower block - 14 1/2" coal; 1/2" shale; 1/2" pyrite.	(85/46	= 1.8)
6. Same locality as Sample 48 SWW above. Fire Clay Rider (?), upper block - 23 1/4" coal; 3/4" bone, 1/4" fusain, 3/4" bone and pyrite partings.	(69/39.5	= 1.7)
7. Gramble Little's truck mine on Highway 30 just west of Jackson, Breathitt Co., Ky. Elkhorn coal - 29 3/4" coal; 1/2", 1/4" shale partings.	(69/45	= 1.5)
8. Ferguson's truck mine near Princess, Boyd Co., Ky. Ashland No. 7 coal, lower block - 24" coal.	(60/38	= 1.6)
9. Dave Edward's truck mine, C., N., SW Sec. 23; T. 4N.; R. 18 W.; Oak Hill Quad, Lawrence Co., Ohio. Ohio No. 4 coal, upper bench - 13" coal.	(75/38	= 2.0)
10. Mallick Coal Co. strip mine, SW-SW-NW Sec. 17, T.10 N., R. 3W., Navarre Quad, Tuscarawas Co., Ohio. Ohio No. 4 coal - 22 3/4" coal, 1/2" bone.	(88/38	= 2.3)
11. Road cut about 1 mile south of Gentryville, Ind., on Highway 45, Spencer Co., Ind. 12" coal with thin shale and fusain partings.	(106/38	= 2.8)
12. Clinchfield Coal Corp., No. 3 Mine, near Dante, Russell Co., Va. Upper Banner coal - 59 1/2" coal with 2 1/2" bone, 2 1/2" shale and coal interbedded.	(88/47	= 1.9)

Locality and coal (continued)	Sample Reading / Background Reading
13. K. and C. Coal Co. truck mine, Clintwood Quad, Dickenson Co., Va. Lower Banner coal - 39 1/2" coal.	(88/47 = 1.9)
14. Pine Creek Coal Co. truck mine, near Bernstadt, Laurel Co., Ky. Baron Fork coal (?) - 35" coal with 2" cannel.	(82/47 = 1.7)
15. Republic Steel Co., Mine No. 1, Road Creek, Pike Co., Ky., Regina Quad. Lower Elkhorn coal - 71" coal with shale partings in upper 16".	(76/47 = 1.6)
16. Republic Steel C o., Mine No. 4, Road Creek, Pike Co., Ky., Regina Quad. Elkhorn No. 3 coal - 44" coal.	(79/47 = 1.7)
17. Mulzer Bros. Coal Co., strip mine, 3 miles S. and 3 miles E. of Gentry ville, Ind. 36" coal.	(65/38 = 1.7)
18. Strip mine 0.08 miles N. of Roseville, Union Township, Jefferson Co., Pa. Middle Kittanning coal (?) - upper bench - 23" coal.	(62/36 = 1.7)
19. Railroad cut 0.9 miles W. of Ben Hur, Lee Co., Va. Devonian black shale - 6' grab sample 11' above railroad.	(356/47 = 7.6)
20. Same locality as 119 SWW above. Devonian black shale - 6' grab sample 40' above railroad	(355/47 = 7.6)

All of the stratigraphic sections measured failed to show rock with radioactivity more than twice background when measured with scintillometer or twenty-inch Geiger tube. The sandstones and coals in the sections checked had extremely low radioactivity, and approximately equal readings. The black carbonaceous shale also showed very low radioacitivity. Marine shale and limestone and coal associated with the marine beds showed about normal radioactivity. Coals associated with dikes were checked in southern Illinois and in Elliott County, Ky. At neither locality was there abnormal radioactivity in the dike rock or in the adjacent coal. The stratigraphic sections checked with either a Geiger counter or scintillometer are listed below.

1. Little Stone Gap 2 miles west of Norton, Wise Co., Va., 1850' of Lee formation, Pennsylvanian age.

2. 1 mile west of Coeburn along the Wise-Coeburn road, Wise Co., Va. 825' of Norton formation, Pennsylvanian age.

3. 5 miles west of Wise along old road from Graden up a left branch of Powell River, Wise Co., Va. 430' of Wise formation, Pennsylvanian age.

4. 3 mile north of Dublin along State Highway 100 on south side of Little Walker Mtn., Pulaski Co., Va. 350' of Price formation, Mississippian age.

5. 6 miles southeast of Gilbert along dirt road at head of Little Cub Creek, Wyoming Co., W. Va. 440' of Kanawha Group, Pennsylvanian age.

6. 2 miles west of West Liberty along U. S. Highway 460 on west side of hill, Morgan Co., Ky. 340' of Breathitt formation, Pennsylvanian age.

7. Along U. S. Highway 119 on east side of Bent Mtn., Pike Co., Ky. 900' of Breathitt formation, Pennsylvanian age.

Conclusions

To date no unusual radioactivity has been found in either the coals or the associated rocks. Very small quantities of uranium are apparently present at 20 localities. Until the laboratory analyses are available no further work is contemplated in these localities; however, if analyses confirm the field radiometric determinations it might be desirable to resample the coals listed to try to determine if the radioactivity is concentrated in some particular horizon.

If the Eastern Coal Reconnaissance project is continued examinations will be made particularly in the Alabama coal fields, the anthracite field of Pennsylvania and Clearfield County, Pa., where some of the coals have been reported to be slightly radioactive.

Western States

New Mexico, by G. O. Bachman

Reconnaissance work on coal and black shale in New Mexico during 1952 was based largely on the presence of minor radioactivity in areas which had been found during the 1951 field season. No deposits of immediate interest were found; however, notable radioactivity was found at a number of previously unreported localities. These localities may be of some interest in pointing the way to new deposits of uranium.

The areas of chief interest where radioactivity was found during the 1952 field season include: Mulatto Canyon, Hosta Butte, and Mariana Pass, McKinley County, N. Mex.; and Cuba Mesa, Sandoval County, N. Mex.

At Mulatto Canyon, Hosta Butte, and Mariana Pass, radioactivity has been found in thin, coaly and carbonaceous lenses in the lower Gibson member of the Mesaverde formation. The radioactive lenses occur at the top of the lower Gibson member at its contact with the overlying Hosta sandstone member. Equivalent uranium content may exceed 0.1 percent at a number of places but the lenese do not exceed six inches in thickness and may be measured from a few feet to tens of feet in length. Thus, these occurrences are not of economic interest. However, they indicate an area which should receive more geologic study.

Minor radioactivity occurs in the caprock of Cuba Mesa in a sandstone of the Nacimiento formation of Paleocene age. The radioactivity occurs in small synclinal depressions near the base of the sandstone. Equivalent uranium of 0.012 percent is contained in these depressions; however, the uranium content is only 0.002 percent. The proximity of Cuba Mesa to La Ventana Mesa makes this occurence of equivalent uranium of some interest to future prospecting in the area.

Other areas examined but with negative results include: the Tocito sandstone on Beautiful Mountain, San Juan County, N. Mex.; Mesaverde coal-bearing rocks in the interior of the San Juan Basin on Chacra Mesa, San Juan County; Mesaverde coal-bearing rocks on the eastern flank of Mount Taylor, Valencia County; and Jurassic and Cretaceous rocks at the south end of the Chama Basin, Rio Arriba County.

Utah, Nevada, Idaho, and Colorado, by D. C. Duncan

Reconnaissance investigations for uranium in marine black shale deposits were continued in Utah, Nevada, Idaho and western Colorado. Field work was started August 18 and was recessed September 23. The investigation was aimed toward completing a field radiometric check of most of the black shale-bearing formations at one or more localities in Utah, and toward a re-examination of the few black shale zones that appeared from the 1951 investigations to have promise of containing more than 0.005 percent uranium. The studies in adjacent parts of Nevada, Idaho and Colorado were made in part to test shale units not represented in the Utah sections and in part to test lateral equivalents of some shale zones containing small amounts of uranium.

Shale units ranging from Pre-Cambrian to early Tertiary in age were examined, although the principal effort was directed toward shale units of late Paleozoic age (Mississippian and Pennsylvanian) which, as shown by earlier sample data, locally contain uranium in amounts of 0.005 percent or a little more. Analyses for samples collected during 1952 indicate that the blanket type shale deposits of minable thickness, or about 5 feet or more, found to date contain less than 0.005 percent uranium.

Black shale units were examined in the following formations:

Utah		No. of Localities	No. of Samples	Uranium content of best samples (percent)
Cottonwood Canyon Series,	Pre-Cambrian	1	1	0.001
Pioche Shale	Cambrian	2	2	0.001
Wheeler formation	Cambrian	1	1	0.0004
Weeks formation	Cambrian	1	2	0.0001
Orr formation	Cambrian	1	2	0.0005
Chainman shale	Mississippian	1	0	-
Cardner limestone	Mississippian	1	8	0.0038
Deseret limestone	Mississippian	2	0	-
Herat shale	Mississippian	1	1	0.0008
Great Blue limestone	Mississippian	1	0	-
Humbug formation	Mississippian	1	1	.0021
Manning Canyon shale	Miss. and Penn.	2	1	.0017
Mancos shale	Cretaceous	1	1	.0002
Green River formation	Tertiary	1	0	-

Nevada		No. of Localities	No. of Samples	Uranium content of best samples (percent)
Unnamed shale unit	Carboniferous	1	8	0.0037
Carbonaceous marlstone				
Humboldt formation	Tertiary	2	2	0.0005
Idaho				
Belt series	Pre-cambrian	1	0	-
Spence shale	Cambrian	1	10	0.0004
Unnamed shale formation	Lower Ordovician	1	2	0.0003
Unidentified shale fm.	Ordovician	1	2	0.0002
Milligen formation	Mississippian	3	8	0.002
Colorado				
Belden shale	Pennsylvania	1	1	0.001
Paradox formation	Pennsylvania	2	4	0.003

Tertiary "lake basin" sedimentary deposits were examined in some of the intermountain basins in northeastern Nevada and central Idaho in reconnaissance search for uranium. The Tertiary sediments ranging from Oligocene to Pliocene in age consist mostly of tuffaceous materials but locally they contain marlstones and some carbonaceous shale or lignite. The tuffaceous sediments locally are slightly radioactive. In place such as a Goose Creek in southern Idaho; Hagerman, Idaho, and the Gamma lignitic shales in Churchill County, Nevada, the Tertiary sequence contains radioactive fossil bones, opalized tuff, and lignitic shales.

A traverse across the Pliocene sediments in the Deep Creek Basin on the eastern margin of White Pine and Elko Counties, Nev., found radioactive bones and opalized tuff in small masses but no carbonaceous sediments.

Examination of carbonaceous rocks in the Humboldt formation of Tertiary age near the towns of Elko and Wells, and near Thousand Springs Creek all in Elko County, Nev. found radiometrically inert carbonaceous sediments, containing essentially no uranium.

Lignitic shale and lignite in the Germer shale member of the Challis Volcanics (Middle Tertiary) were examined and sampled at localities near Salmon, Lemhi County, Idaho and near Challis, Custer County, Idaho, completing an inventory of lignites of the area started in 1951 by Hail and Gill (TEM-446). The lignities sampled in 1951 contain essentially no uranium.

Bituminous coals of the Mesa Verde group (Upper Cretaceous) were tested radiometrically at localities near Helper and Hiawatha in Carbon County, Utah. The coals tested radiometrically inert and were not sampled.

A report, assembling results of the black shale reconnaissance work of the Geological Survey in western states during 1951 and 1952 has been in preparation since October 1, 1952. Although the data are not fully assembled, the uraniferous shale deposits found to date appear to be either too low grade or too small to be of economic interest.

Considering the generally negative results of the black-shale reconnaissance investigations to date a review of possibilities of finding useful amounts of uranium in the black shales is being made. Possibly about one-half of the recorded black shale formations in the western states have been examined at one or more localities. The work to date has been pointed mainly toward search for extensive units similar to the Chattanooga. Although the possibilities that similar deposits may occur in western United States have not been eliminated, the probabilities of finding such widespread deposits of large size and equal or better grade seem poor.

Smaller areas of more highly uraniferous shales, comparable in quality and size to those in Sweden, may still be found in the United States. Because the effort required for a thorough search for such deposits by systematic reconnaissance is tremendous, two short cuts are being considered: (1) review of information on paleogeographic setting and geochemistry of known uraniferous black shales in an effort to define the geologic controls responsible for their origin; and (2) undertake a fuller inventory of black shale samples and gamma-ray logs collected by the oil companies. The mechanism for undertaking this will be explored in the near future with the Commission.

Parts of Colorado, Wyoming and Montana, by J. R. Gill

Reconnaissance for uraniferous coals and shales in central, southwestern, and northeastern Colorado, eastern Wyoming and southeastern Montana was begun June 18, 1952, and terminated October 1, 1952. The results of the field work are discussed below for the parts of the three states covered:

Colorado, Wyoming, and Montana.

Central, southwestern and northeastern Colorado.--Reconnaissance in Colorado consisted of a radiometric survey with a Beta Gamma Survey Meter, Beckman

Model MX-5 of coal, carbonaceous shale and marine black shale wherever encountered. A brief reconnaissance was made of the South Park coal field, Park County, the Crested Butte and Paonia coal fields of Gunnison and Delta Counties and the coal-bearing area in the vicinity of Mancos and Durango, Montezuma and La Plata Counties. A majority of the coals and carbonaceous shales examined were of Cretaceous age and none contained over 0.002 percent uranium in the ash. One thin impure coal in the Belden formation of Pennsylvanian age was discovered about 18 miles southeast of Crested Butte. This coal had 45.5 percent ash and contained 0.006 percent uranium in the ash.

The only promising marine black shales discovered in the examination of the above areas were those of the Hermosa formation of Pennsylvania age that are extensively exposed in the San Juan Mountains north of Durango. Of ten samples collected along the Durango-Ouray highway, five contained between 0.002 and 0.004 percent uranium. Even though the uranium content is exceedingly low, it does point up the possibility that shale with higher uranium content may be found by a more detailed investigation.

Tertiary and Cretaceous coals in the vicnity of Pagosa Springs, Archuleta County, are not appreciably radioactive as none have a uranium content of over 0.002 percent in the ash.

Reconnaissance of the Trinidad, Canon City and Colorado Springs coal fields of Las Animas, Fremont and El Paso Counties did not lead to the discovery of coal or carbonaceous shale with uranium content of more than

0.003 percent in the ash.

The reconnaissance work in Colorado was terminated with the examination of the Tertiary and Cretaceous coals of the Denver Basin. Strip mines, outcrops, mines and mine dumps in El Paso, Douglas, Lincoln, Arapahoe, Adams, Boulder, Larimer, Weld, Morgan, Washington and Logan Counties were examined without notable results. One possible exception was the discovery of a 3-foot lignitic shale exposed in an abandoned mine about 12 miles north of Fort Collins, Larimer County. This shale contained 0.006 percent uranium in the ash and 0.005 percent uranium in the sample. The lack of natural exposures throughout the Denver Basin makes the evaluation of the potentialities of the area exceedingly difficult. Even though the results from surface examinations are discouraging it is believed that exploratory drilling would be essential before the area could be eliminated from further consideration. Such type of exploration would be very helpful in the norther part of the basin where the potential source beds of uranium in the White River formation of Oligocene age unconformably overlies the coal-bearing Laramie formation of Cretaceous age.

Eastern Wyoming.--Work in Wyoming consisted of a brief reconnaissance of the two eastern tiers of counties, namely, Platte, Goshen, Converse, Weston, Campbell, and Crook.

The reconnaissance of the Goshen Hole, Goshen County, was hindered by the lack of natural outcrops and a heavy cover of vegetation. Coal was not observed but from published accounts and drillers' logs it is known to be present. Additional work may be done in this area.

Uraniferous black shales from the Hartville formation of Pennsylvanian age have been described from cores from several oil wells to the east of the Hartville Uplift. The Hartville-Glendo area was investigated on the possibility that these shales might outcrop within the area. Examination of the Hartville and adjacent formations did not result in the discovery of any radioactive black shale. However, a number of long-abandoned copper mines and prospects contain small quantities of radioactive rocks. In all cases, the radioactivity was associated with secondary copper minerals. In the past, some copper has been mined from the Whalen group (pre-Cambrian) and the Gurnsey formation (Mississippian). In many places in the Hartville area, the Gurnsey formation unconformably overlies the metamorphosed sedimentary rocks of the Whalen group. The copper occurs as replacement deposits in the form of small lenses and pods along the base of the Gurnsey limestone. A grab sample of copper-impregnated limestone from the base of the Gurnsey formation at the Michigan mine, NW$\frac{1}{4}$ sec. 24, T. 30 N., R. 65 W., Goshen County, contained 0.027 percent uranium. A grab sample of copper impregnated schist from the North Copper Belt mine contained 0.012 percent uranium and a sample of dolomite partly replaced with copper from the South Copper Belt mine contained 0.023 percent uranium. The Copper Belt mines are located in the south half of sec. 2 and the north half of sec. 11, T. 31 N., R. 64 W., Goshen County. The minerals in the two Copper Belt mines occur along and near a fault in the pre-Cambrian dolomites and schists of the Whalen group. Numerous small prospect pits in the vicinity of the Copper Belt and Michigan mines give radiometric indications of uranium. Even though the uranium content of the copper-bearing rocks is not high, their occurrence is significant since it extends the uranium mineralized area south from Lusk by about 15 miles and north from the previously reported radioactive copper Botton prospects by about 10 miles. A detailed study of the occurrences in the pre-Cambrian Whalen group as exposed along the eastern margins of the Hartville Uplift may be taken.

Reconnaissance northward from the Hartville Uplift along the eastern margin of the Powder River Basin and along the west flank of the Black Hills in the Aladdin, Sundance and Skull Creek coal fields, with but one exception, did not result in the discovery of any radioactive coals or shales. This one exception was a bed of radioactive coal in the Cambria coal field.

In the Cambria coal field near Newcastle, Weston County, one lenticular bed of coal, 4.8 feet thick is moderately radioactive, having a uranium content of 0.0085 percent in the ash. This bed is probably the stratigraphically highest coal in the coal-bearing Lakota sandstone. Other lower coals that were mined in the past for steam coal and coke were examined but they did not give radiometric indications of uranium. However, a sample of coke produced from these lower coals contained 0.008 percent uranium in the ash. Therefore, even though these lower coals are apparently radiometrically inert, they do contain small quantities of uranium, probably less than 0.002 percent in the ash.

<u>Southeastern Montana</u>.--Reconnaissance of the Ekalaka lignite field, Carter County, resulted in the most promising discovery of the 1952 field season. Several beds of radioactive lignite were discovered in the Ekalaka Hills, about 10 miles south of the town of Ekalaka. The lignites occur

in what is apparently the Ludlow member of the Fort Union formation of Paleocene age and are unconformably overlain by several hundred feet of massive tuffaceous sandstones of the Arikaree formation of Miocene (?) age.

In the SE$\frac{1}{4}$ sec. 25, T. 1 N., R. 58 E., three beds of radioactive lignite are exposed. The stratigraphically highest lignite is 3.2 feet thick, has an ash content of 47.9 percent and contains 0.019 percent uranium in the ash. The upper 1.5 foot of this bed contains less ash (34.5 percent) and more uranium (0.057 percent in the ash). The middle 0.5 foot of this 1.5 foot section contains 0.14 percent uranium in the ash. The second stratigraphically highest bed is 2.0 feet thick and contains 0.006 percent uranium in the ash. The third stratigraphically highest bed is 8.0 feet thick, has an ash content of 33.8 percent and a uranium content of 0.014 percent in the ash. This bed is separated from a fourth bed by 3.0 feet of carbonaceous shale. The fourth bed is over 9 feet thick and apparently is inert radiometrically and, therefore, it was not sampled. Since all of the above samples are of weathered lignite it is quite likely that the ash values are too high and consequently the uranium values too low. These lignite beds are lenticular but it is possible to trace their outcrop for 3 or more miles. Samples of these beds have been collected at several localities but as yet analytical data are not available. The areal extent of the lignites cannot be accurately determined until the mapping that was initiated at the close of the field season can be completed. Even though these beds are thought to underlie at least 3 square miles, exploratory drilling will be required before accurate reserve estimates can be made.

Summary.--Only 6 general areas out of the many that were examined during the past field season seem worthy of additional study. They are listed below in their order of apparent importance.

1. Ekalaka lignite field, Carter County, Mont. (uraniferous lignite)-Completion of mapping and additional sampling of lignites in the Ekalaka Hills prior to a limited amount of exploratory drilling. Additional reconnaissance of adjacent areas.

2. Hartville Uplift, Goshen County, Wyo. (radioactive copper deposits)-Detailed study of the pre-Cambrian rocks, with regard to the contained minerals. A possible airborne radiometric reconnaissance of this area.

3. San Juan Mt. area, southwestern Colorado (radioactive black shales in the Hermosa formation)-Additional reconnaissance of the Hermosa formation and it equivalents in southwestern Colorado.

4. Goshen Hole, Goshen County, Wyo. (possible radioactive coal)-Re-examination of this area with a jeep-mounted auger.

5. The Denver Basin of northeastern Colorado (possible radioactive coal)-One or two exploratory core holes. Possible location: North of Briggsdale or New Raymer, Weld Co., Colo. and so located as to penetrate a portion of the White River formation and the underlying coals of the Laramie formation.

6. The Cambria coal field, Weston County, Wyo. (radioactive coke and coal)-Possibly map the radioactive coal bed as well as determine number of tons of coke in the waste coke pile at the site of the old coke ovens. This coke is reported to contain gold and silver values as much as $2.00 a ton. (Gold $20.00 per ounce at the time of the report.)

California and adjacent states, by G. W. Moore

During the 1952 field season a three-months reconnaissance investigation was conducted in California and parts of Oregon and Nevada to explore the possibilities of the association of uranium with coal and other carbonaceous deposits. Most of the exposures of coal in California which have been reported in the literature or described in the files of the California Division of Mines were visited. These and several localities in adjacent parts of Oregon and Nevada total 85 in number. Examinations were in 21 of the 58 counties of California, three counties in Oregon, and three in Nevada. Mildly radioactive volcanic rocks in the vicinity of some of the coal occurrences were studied and samples of these and of spring water issuing from them were collected for analyses. In addition, samples of bituminous sandstone were collected from several localities.

A complete evaluation of the past summer's reconnaissance work in the region cannot be made fully until the results of the analyses have been received. No further work is planned unless analytical results are more promising than presently anticipated.

Wyoming, by J. D. Love

Reconnaissance work in Wyoming in the past 6 months was devoted chiefly to studying uraniferous volcanic rocks that may contain uranium deposits of commercial interest and that are potential source rocks for uranium in carbonaceous material and associated rocks in older sequences. The chief areas examined are the Jackson Hole area in northwestern Wyoming, the Miller Hill area in south-central Wyoming and the Split Rock area in the central part of the state. A number of other areas also were examined (fig. 8). The chief objective of the work was to acquire basic data on the stratigraphy and structure of the potential source rocks that are known to be slightly radioactive.

Jackson Hole area.--In the Jackson Hole area, a sequence of hitherto undescribed Miocene and Pliocene strata about 9000 feet thick was studied. Two new formations were defined and thrust-fault and normal fault structures were worked out. Thrust faulting involving rocks as young as Pliocene has not previously been recognized in Wyoming.

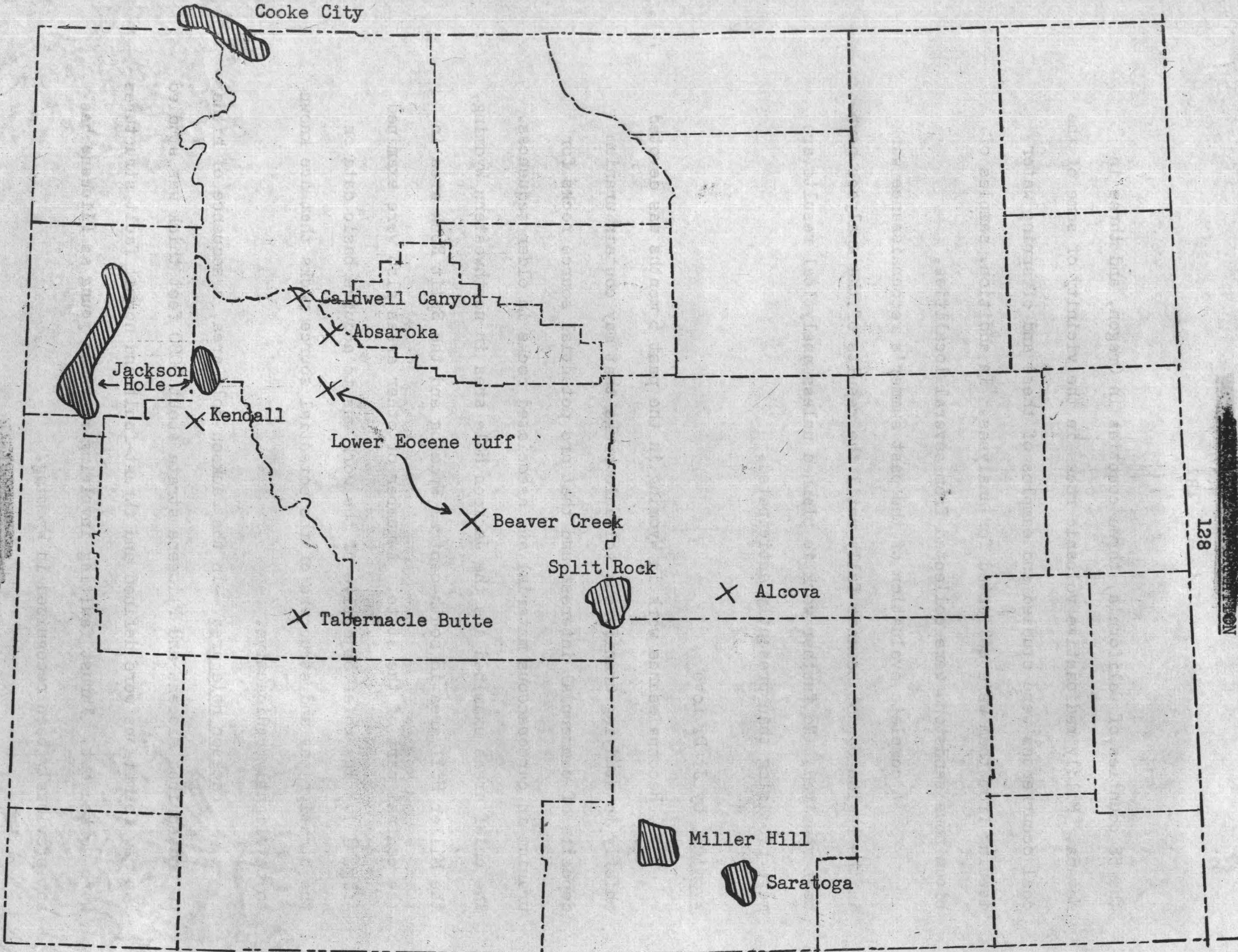


Fig. 8 .—Index map showing areas examined under Wyoming reconnaissance

A section of Pliocene rocks contains 29 pumicite beds, ranging in thickness from 5 feet to 71 feet, and averaging 22 feet. The section contains a total of 663 feet of pumicite. As much as 8,000,000 tons of pumicite containing 0.001 percent uranium is present in an area no more than 1,000 feet wide along the outcrop and assumed to be 1,000 feet long down the dip. The total tonnage in the vicinity is much greater, of course. The pumicite is easily accessible by road, is within 10 miles of the town of Jackson, and is on federally-owned land in the National Elk Refuge.

Algal (?) limestones totaling 1128 feet in thickness were measured in a sequence of Pliocene rocks. Many of these limestones contain 0.0005 to 0.001 percent uranium. Some evidences of secondary concentration of uranium were discovered but it was not possible to locate the areas of greatest concentration without a scintillometer.

A report presenting analyses, a summary geologic discussion, possibilities of uranium deposits and plans is being prepared. A report describing the geology in greater detail also is being prepared for publication.

Additional reconnaissance surveys with scintillometers are planned for the Oligocene, Miocene, and Pliocene strata and the coal-bearing sandstones of the underlying Cretaceous, Paleocene, and early Eocene rocks in the northern part of the Jackson Hole area.

<u>Miller Hill area</u>.--The Miller Hill area in south-central Wyoming was recommended for airborne radiometric surveys on the basis of juxtaposition of the Browns Park (?) formation of Miocene age, chiefly of volcanic origin, and older, coal-bearing rocks. The western part of the

area was flown in October 1952 and two small anomalies were located. Ground check by the writer and J. D. Vine found that the anomalies were located in a sequence of Miocene algal limestones from which samples of individual beds about a foot thick contained 0.13 and 0.15 percent uranium. Eight out of 11 other samples of 1-foot beds through a section about 220 feet thick contained 0.010 percent uranium, or slightly more. This is the first time that an apparent uranium source rock in Wyoming has been found to contain uranium in such high grade. Water samples from springs in the Miocene rocks contained 0.01 parts per million uranium.

A report, including a map, analyses, and discussion of the stratigraphy, is being prepared. Not enough is known to speculate on reserves.

Additional work in the Miller Hill area is planned for fiscal year 1954. The airborne radiometric survey conducted this season may be extended eastward early in the spring. The airborne survey, followed by ground checking, should include the Browns Park (?) formation and outcrops of the Muddy sandstone, the Cloverly and Morrison formations undivided, and the Frontier, Mesaverde, Lance, and Fort Union formations where the Browns Park (?) formation directly overlies them, or where it may once have overlain them.

Split Rock area.--The possibilities of uranium deposits in the Split Rock area were described in TEM-282 (Love, 1952). An airborne radiometric survey was made in October 1952 but results have not been ground checked. Work in the area was confined to measuring and sampling sections of Miocene and Pliocene (?) strata and to studying the areal relationships between Pliocene (?), Miocene, and older rocks. Analyses from rock samples recently submitted are not available. Water samples from two wells in the

Pliocene (?) rocks contained 0.042 and 0.023 parts per million uranium. Widespread dolomitic algal reefs in the strata show some secondary concentrations of uranium and should be investigated since samples from similar algal reefs in the Miller Hill area are high in uranium content.

A short report supplementing TEM-282 is being prepared. In addition, a report describing the geology of the area is being prepared for publication.

Airborne anomalies detected in the October 1952 survey will be ground checked with a scintillometer and any promising leads thus discovered followed up. If results of reconnaissance are sufficiently promising, the geology of the area may be mapped in detail. New topographic maps are available.

Other areas.--Reconnaissance examinations were made and samples collected from the following sequences and places (fig. 8):

Rhyolite, Cooke City-Clark Fork area, northwestern Wyoming

Oligocene and Pliocene volcanic rocks, Absaroka Mountains

Pleistocene strata, near Kendall Ranger Station

Middle Eocene rocks, Tabernacle Butte

Lower Eocene Tuffs, Wind River Basin

White River formation, near Alcova

Pliocene rocks, Saratoga area.

The sample of rhyolite from the Cooke City-Clark Fork area was reported to contain 0.016 percent uranium. This analysis is believed to be much too high but no material is left for a check analysis. The sample must be discounted for the present but other samples will be obtained at the first opportunity. Analyses are not available for the samples from other areas. A sample of volcanic rocks of probable Pliocene age in Caldwell Canyon, collected by the writer in 1937, contained 0.009 percent uranium.

Data from these miscellaneous areas will be included in a report of state-wide scope on Tertiary and Quaternary source beds of uranium. This report should be completed during the winter.

Continued study of potential source beds for uranium in Wyoming is justified because of its contribution to the search for uranium deposits. For example, the Pumpkin Buttes area was one of five areas recommended for investigation in 1950 and the Miller Hill area was one of 11 areas recommended for 1952. A second of these 11 areas is the Devils Tower area where the Homestake Mining Company made extensive airborne radiometric surveys in 1952 and discovered a number of small carnotite deposits. The areas recommended in 1950 and 1952, not all of which have been flown, were selected largely on theoretical concepts based on a large quantity of information from other geologic investigations. These concepts have been placed on a much firmer base as a result of studies in 1952. Continued field research along the same lines will pay dividends by amplifying and modifying these concepts so that an even greater margin of success can be obtained.

Mineralogy and geochemistry of lignite and coal

by Maurice Deul and I. A. Breger

The mineralogic studies in this report were carried out by Maurice Deul with the assistance, since June 1952, of Samuel Rubenstein. The chemical studies were carried out by Irving A. Breger. Mr. Robert Meyrowitz was recently assigned to the Project and is currently devoting his full time to the organization of microchemical work for this project. Analytical assistance has been obtained, as required, from the staff of the Trace Elements Section Washington Laboratory, where all the work discussed below has been carried out. TEI-284, entitled "Current status of investigations on the geochemistry and mineralogy of uraniferous lignites" by I. A. Breger and M. Deul presents in detail the results of the investigations during the period.

Almost all the detailed studies discussed in this report were carried out on a sample from the top bed of uraniferous lignite from the Mendenhall Strip Mine, Harding County, S. D. This material contains 42 percent bed moisture, 32.4 percent ash on a dry basis, and 0.12 percent uranium in the ash.

By means of heavy-liquid separations, a mineral-free concentrate of the coal containing 13.8 percent ash and 0.31 percent uranium in the ash was obtained. The minerals (gypsum, 69 percent; jarsoite, 10 percent; quartz, 2 percent; kaolinite and clay minerals, 19 percent; calcite, trace) contain only 7 percent of the uranium in the original coal indicating an association of the uranium with the organic components of the lignite.

Preliminary batch extractions showed that 88.5 percent of the uranium could be extracted from the lignite by two consecutive treatments of the coal with boiling 1 N hydrochloric acid. Continuous extraction with 6 N hydrochloric acid, removed 98.6 percent of the uranium.

Continuous treatment of columns of the coal (approximately 750 x 35 mm) with water, 1 N hydrochloric acid, or 6 N hydrochloric acid, suggested the possibility that the uranium was held in the lignite by ion exchange.

To further investigate this, a solution of lanthanum nitrate was passed through a column of the coal to displace any base-exchanged uranium. This work indicated that only 1.2 percent of the uranium in the coal is held by ion exchange. Furthermore, the elutriation experiments indicated that the uranium is held in the coal as an organo-uranium compound or complex soluble at a pH below 2.18.

Because it is thought that certain phases of many organic geochemical problems may best be solved by correlation studies, equipment has been purchased and set up for the microchemical determination of carbon, hydrogen, nitrogen, sulfur, and oxygen in organic substances. Excellent C/H ratios have already been obtained with a standard sample. Equipment for microfunctional group analysis, i.e., acyl, alkoxyl, and alkimide, has also been obtained, and the purchase of an infrared spectrophotometer in being considered.

Present work and plans

Extreme fine grinding of the mineral-free Mendenhall lignite, using a ball mill and kerosene, is being carried out to determine if the ash content of the coal can be further reduced by the separation of finely disseminated minerals which may still be present in the coal.

Work has been planned to characterize the organic substances associated with the uranium in the coal.

Investigations will be carried out to determine if there is a relationship between the pH of a coal and its uranium content within a restricted area. If this work is successful it may simplify the field investigations on uraniferous lignites.

Radioactive disequilibrium in the sulfate minerals isolated from the coal will be studied to determine if the lignite was weathered in more than one stage.

The association of uranium with trace elements in the coal will be studied on a sample-to-sample basis by means of punched card techniques to establish any possible relationships which may exist.

Coals other than the Mendenhall lignite will be studied.

Coal petrographic studies on Dakota lignite
by J. M. Schopf

Reserve portions of all cores processed at the Coal Geology Laboratory provide material for coal petrographic research on the organic associations of uranium. To serve this purpose best, high moisture coal should not be permitted to dry. Blocks of representative types of coal have been cut from the reserve portions of the core during core processing and stored in water so that good thin sections can be prepared with minimum difficulty.

Studies are still largely in preparational stages although thin sections have been made of most of the blocks taken from cores of Dakota lignite. About 350 of these lignite sections of varying quality have been prepared. Difficulty has been experienced in making sections of weathered coal such as that from the column specimen from the Mendenhall strip pit in the Slim Buttes area. Because of the special importance of this material, a vacuum embedding procedure to thoroughly impregnate the coal with hot carnauba wax has been adopted to prepare the coal for making thin sections.

Results are very promising.

Micro-determinations of anthraxylon, translucent attritus, opaque attritus, fusain and mineral matter will be made from the thin sections. The microscopic composition will be correlated with the radioactivity of the material sectioned.

Initial exploratory work of this nature has shown that radioactivity is not correlated with the presence of thick woody bands, although these may in some instances be highly radioactive. It also has shown that peaks of considerable radioactive contrast may be no more than 1/2 inch in thickness. All minor laminae of this character are obscured by less refined methods of sampling so that only average values, possibly very misleading from the standpoint of primary occurrence, are ordinarily reported.

The stripping film technique also will be used to determine semi-quantitatively the location of uranium in the lignite. The method should serve to indicate any preference for distinctive phyterals or zonations of occurrence within any of the coal constituents. Materials for these studies have been assembled and a few slides have been covered with film for extended exposure. The method appears to be practical for selected specimens that are known to have significant uranium concentrations, but the general utility of the method is not yet certain. Difficulty is expected when the stripping film method is used with water-soluble, weathered lignite.

The necessity for correctly processing cores to obtain reliable samples for coal petrography research, and the bulk and urgency of such work in the past six months, has made it impossible to carry on consistant detailed coal petrographic study. It is believed that significant research on this problem can be carried out during the next half-year period and a more complete report will be submitted in June 1953. The effective planning of these studies recently has been much facilitated by access to field information that relates to the core materials.

District studies

Goose Creek district, Cassia County, Idaho
by William J. Mapel

The purpose of field work in the Goose Creek district (fig. 9) was to determine the extent, thickness, and grade of uranium-bearing carbonaceous shale and lignite in the Payette and Salt Lake formations of Miocene and Pliocene age. This work was completed during the 1952 field season. An area of about 240 square miles was mapped on aerial photographs at a scale of 1:30,000. Reconnaissance studies were made and carbonaceous shale sampled in the Grouse Creek area, northwestern Boxelder County, Utah, and in the vicinity of Elko, Nevada, but no uranium in significant quantities was found.

The thickest and highest-grade uranium-bearing carbonaceous shale found in the Goose Creek district underlies an area of about 12 square miles in T. 16 S., R. 21 E., Cassia County, Idaho. About 15 percent (280 tons) of the estimated total reserve of uranium in this area is overlain by less than 100 feet of overburden and thus may be recovered by stripping. Mild radioactivity was observed in carbonaceous shales in other parts of the district, principally in T. 15 S., R. 21 E., but for the most part the beds that crop out are thin and probably contain little uranium.

A reserve estimate of uranium present in the Goose Creek district,

[illegible] during [illegible] period and [illegible]
[illegible] 1953. The effective [illegible]
[illegible]
[illegible]

[illegible]

[illegible] Creek [illegible] County, [illegible]
by [illegible] L. [illegible]

The purpose of [illegible] in the [illegible] (Figure 3 [illegible]) was to [illegible] the [illegible] and grade of uranium-bearing carbonaceous [illegible] in the [illegible] formations of [illegible] during the 1952 field season. [illegible] [illegible] [illegible] [illegible] County, Idaho, [illegible] [illegible] [illegible] an area of about 12 square miles [illegible] County, Idaho. About 15 percent [illegible] [illegible] [illegible] [illegible] [illegible]

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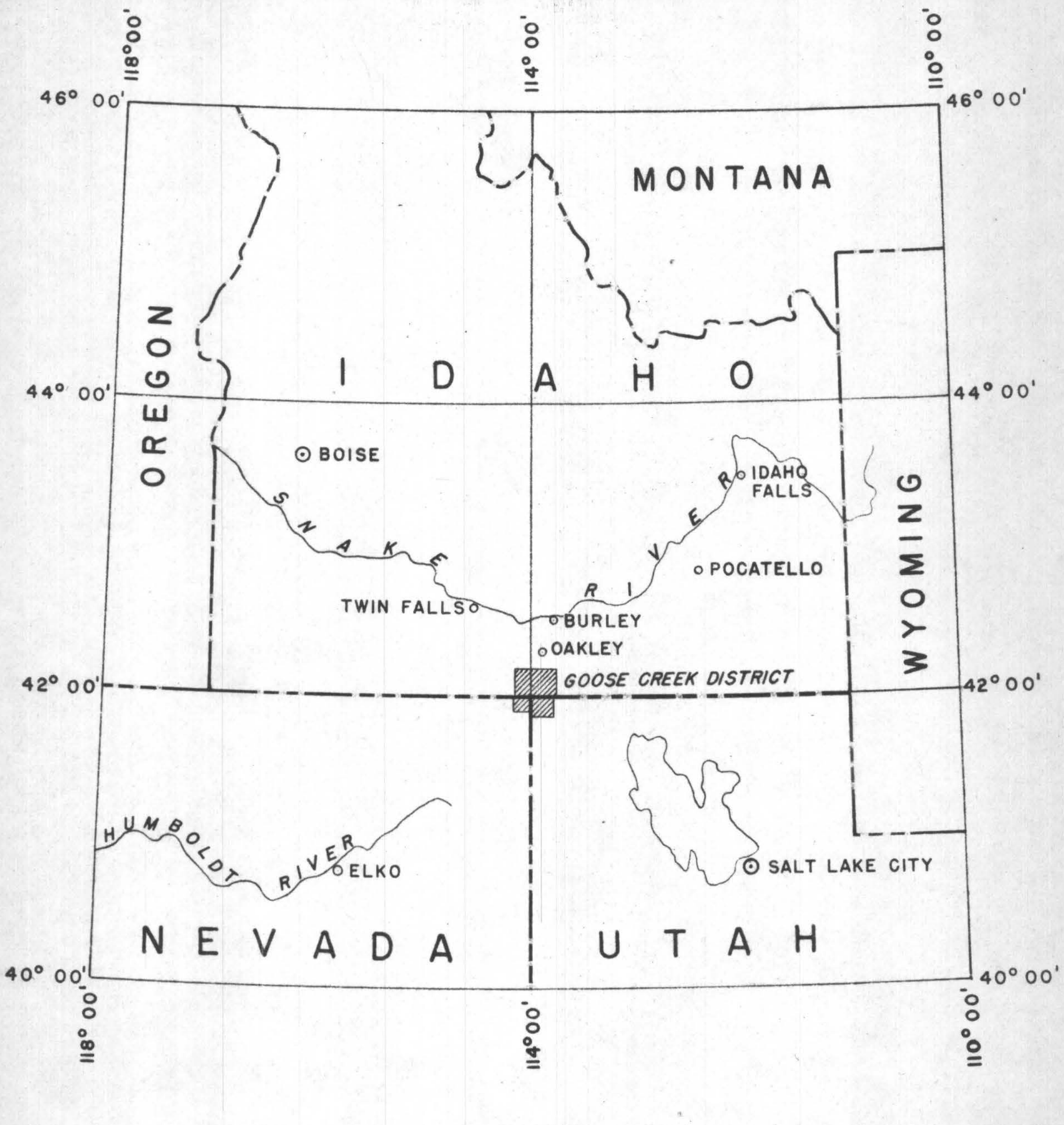

INDEX MAP SHOWING LOCATION
OF GOOSE CREEK DISTRICT

0 50 100
MILES

FIG. 9

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Table 1 .--Indicated uranium reserves, Goose Creek district, Cassia County, Idaho 1/

Bed	Thickness (weighted average in feet)	Area (acres)	Uranium (weighted average percent)	Total carb. shale (short tons) 2/	Total uranium (short tons)	Strippable reserves 3/ Carb. shale (short tons)	Strippable reserves 3/ Uranium (short tons)
Barrett	2.1	300	0.013	T. 15 S., R. 21 E. 620,000	81	-	-
Barrett	2.5	3,410	0.0056	T. 16 S., R. 21 E. 8,400,000	470	2,100,000	120
In beds 3.0 feet or more thick containing 0.005 percent or more uranium.							
Barrett	3.0	100	0.006	T. 15 S., R. 20 E. 290,000	20	-	-
Barrett	5.2	80	0.007	T. 15 S., R. 21 E. 410,000	30	-	-
Barrett	4.2	4,050	0.009	T. 16 S., R. 21 E. 17,000,000	1,500	1,800,000	160
GRAND TOTALS	3.4	7,940	0.008	26,720,000	2,101	3,900,000	280

1/ In beds 1.5 to 3.0 feet thick containing 0.005 percent or more uranium.
2/ 980 tons of carbonaceous shale per acre-foot assumed in all calculations.
3/ Under less than 100 feet of overburden.

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based on reconnaissance studies during the 1951 field season, has been listed in an earlier report by W. J. Hail, Jr., and J. R. Gill (TEM-391 in preparation). This information, modified by later analytical data, is summarized in table 1 . More precise reserve estimates will be possible when analyses of samples submitted during the 1952 field season are available.

Core drilling in T. 16 S., R. 21 E., Cassia County, Idaho, is being considered as the best means of extending the proven reserves of uranium.

Red Desert area, Sweetwater County, Wyoming
by Harold Masursky

The 1952 field work in the Red Desert had a fourfold purpose:
(1) to di...

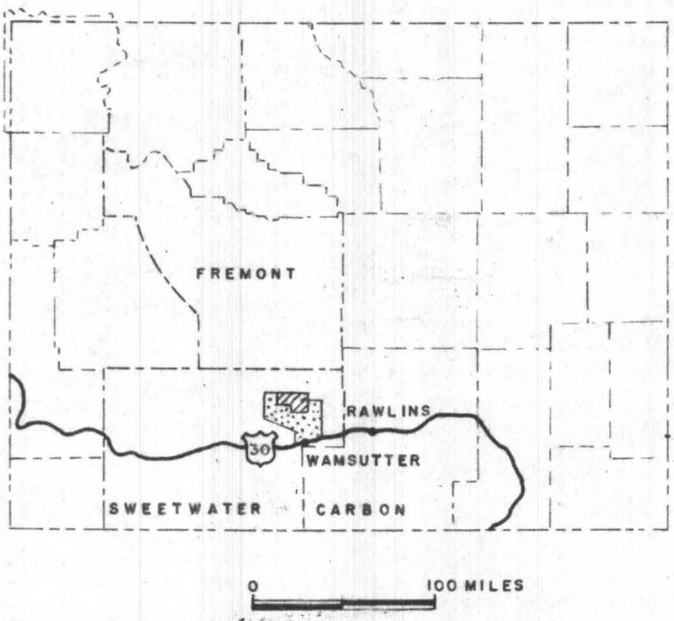


Figure 10. Index map of Wyoming

Area of exploratory drilling for uranium-bearing coal - 1952 (See Fig. 12)

Area mapped in 1951

A core-drilling program was carried out to outline coal reserves and to obtain heating values and uranium grade from unweathered samples. Eleven holes were completed totaling 2,493 feet (fig. 11). The areal distribution of these holes is shown in fig. 12. The drilling was confined to the northern part of the Red Desert area, because from surface examination this area apparently contained the highest grade deposits. It originally had been planned that drilling would test the southern part of the Red Desert area, also, but funds were not available.

Results and conclusions

(1) The core drilling indicated that large deposits of uranium-bearing coal underlie the alluvium-covered lake flats. Additional strippable reserves with coal beds in excess of two and a half feet in thickness and overlain by less than 75 feet of overburden are outlined in figure 12. The strippable areas in Lost Creek flat are well established; those in Battle Springs flat are still quite tentative.

(2) Additional mapping in the area south of that shown in figure 12 slightly increased the reserves of uranium-bearing coal.

(3) The higher concentration of uranium in coal beds in juxtaposition to permeable horizons and to topographic highs reinforce the epigenetic hypothesis of origin for the uranium.

(4) Age determinations from the fossil collections submitted to the National Museum will make possible correlation of the mapped units with the type sections in adjacent areas.

A preliminary computation of coal and uranium reserves in the area of core drilling is shown in table 2. Uranium grade is estimated from

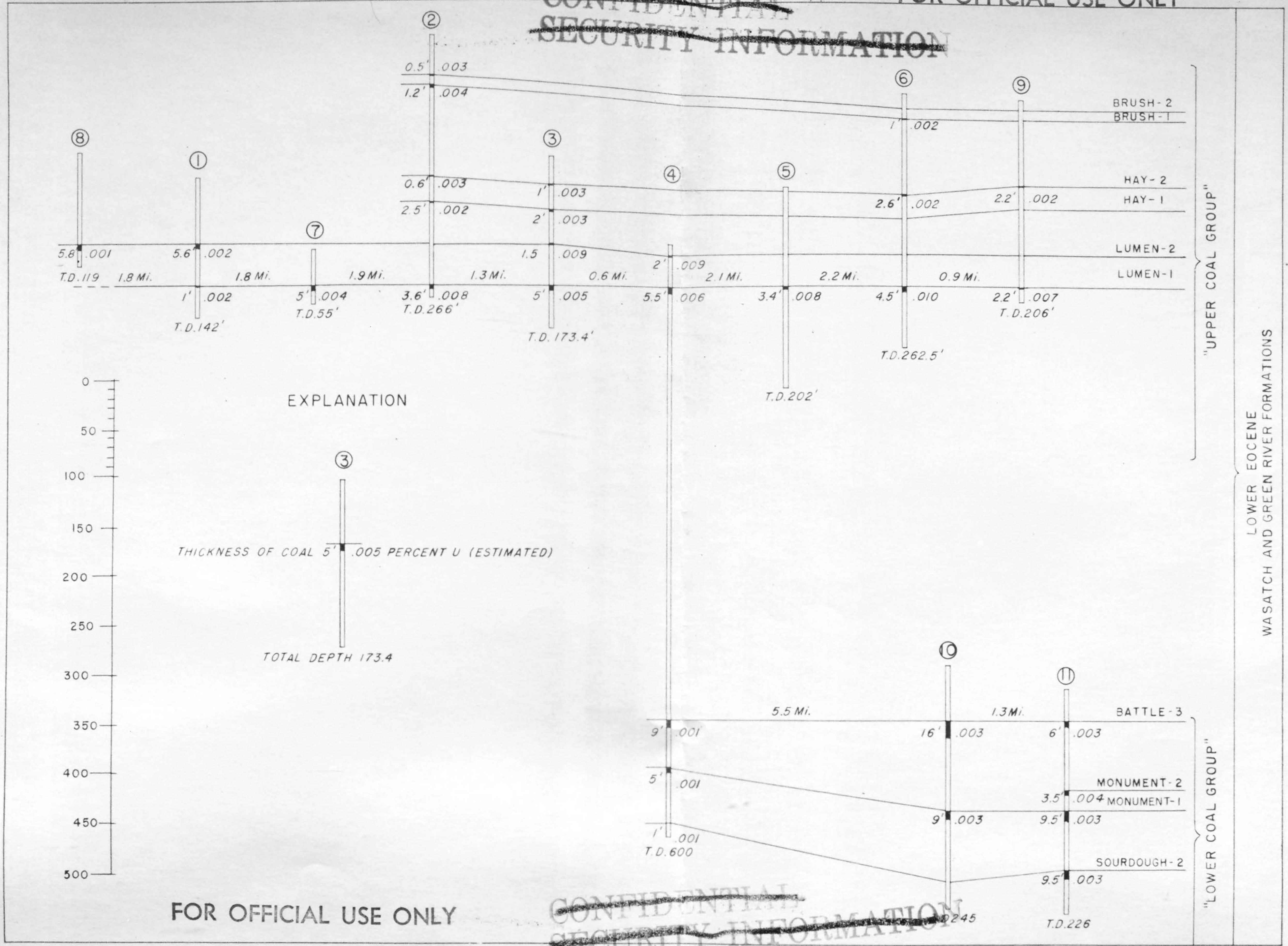
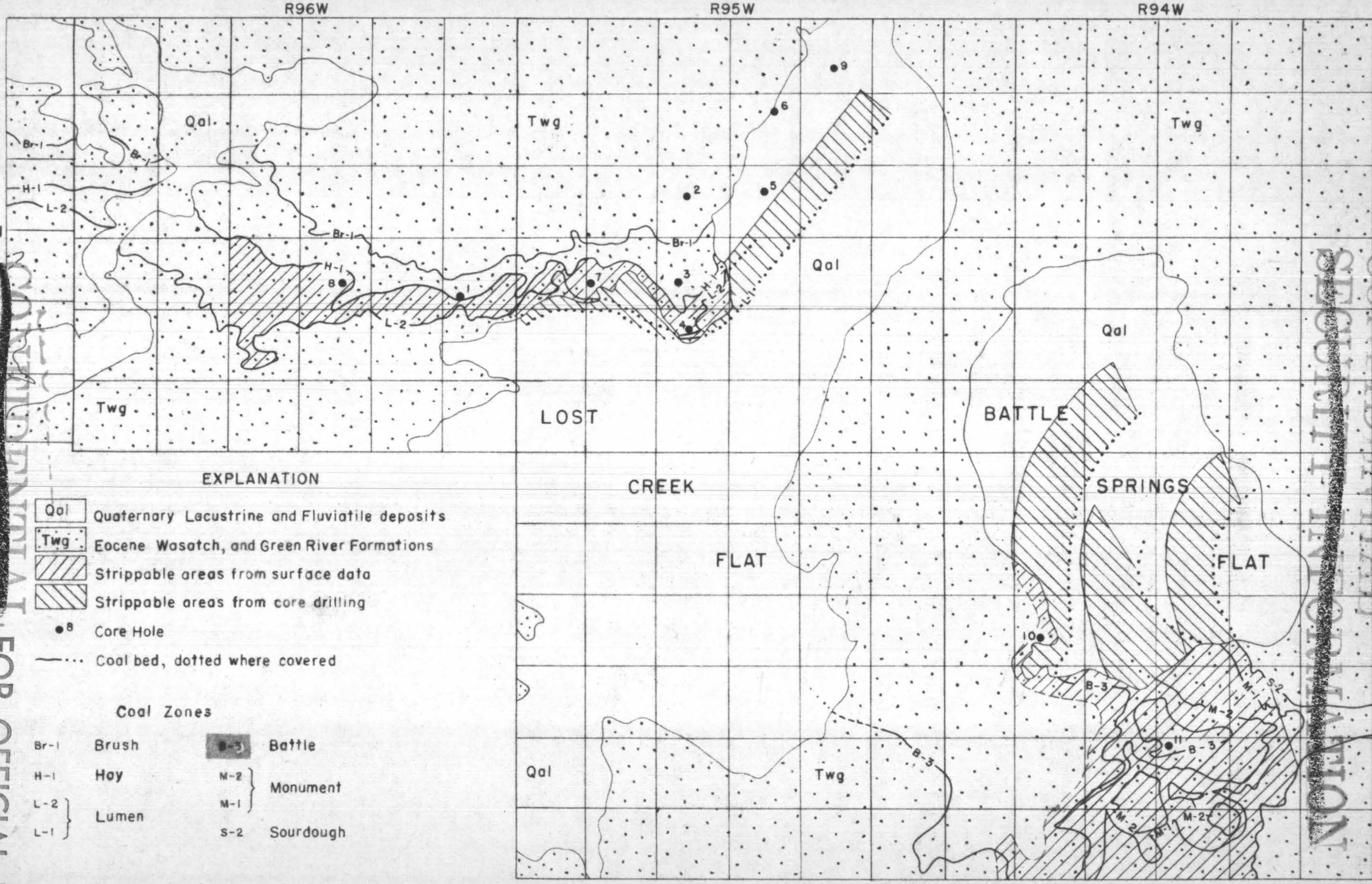


FIGURE 11 DIAGRAM SHOWING THICKNESSES AND ESTIMATED URANIUM CONTENT OF COAL BEDS IN CORE HOLES, RED DESERT AREA, SWEETWATER COUNTY, WYOMING



SKETCH MAP SHOWING LOCATION OF CORE HOLES AND STRIPPABLE AREAS OF URANIUM BEARING COAL IN THE NORTHERN PART OF THE RED DESERT, SWEETWATER COUNTY, WYOMING

FIGURE 12

[redacted]

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[redacted]

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Table 2.--Summary of estimated uranium-bearing coal reserves, Red Desert area, Sweetwater County, Wyoming

Township and Range	Name of bed	Acres (acres)	Thickness (feet)	Uranium percent	Coal (short tons)	Uranium (short tons)
			Reserves from surface data			
T. 24 N., R. 95,96 W.	Lumen 2	2,189	2.8	0.005	10,419,640	521
	Lumen 1	768	4	0.005	5,222,400	261
			Reserves added from coring data			
T. 24 N., R. 95,96 W.	Lumen 2	512	2	0.006	1,740,800	104
	Lumen 1	1,772	4.1	0.005	11,213,200	560
			Reserves from surface data			
T. 23 N., R. 94 W.	Battle 3	1,587	7.5	0.003	19,534,250	585
	Monument 1	3,072	6.5	0.005	33,945,600	1,697
	Sourdough 2	3,174	6.5	0.004	35,072,700	1,203
			Reserves added from coring data			
T. 23 N., R. 94 W.	Battle 3	1,949	10	0.005	33,130,000	1,657
	Monument 1	947	10	0.007	16,600,000	1,127
	Sourdough 2	1,158	5	0.008	9,843,000	787
				Totals (rounded)	176,700,000	8,500

Reserves from 1951 data

As a result of surface data compiled in 1951 in Twps. 20, 21 and 22 N., Rgs. 92, 93, 94 and 95 W. an estimated total of about 513,800,000 tons of sub-bituminous coal containing about 11,600 tons of uranium is present in beds in two and a half feet or more in thickness and with less than 75 feet of overburden.

1/ Tonnage estimates are based on 1,700 tons of coal per acre foot.

radiometric determinations supplied by Schopf. Reserves based on last year's field and laboratory data for the remainder of the mapped area with slight modifications are also included.

<u>Plans</u>

1. Two reports, a preliminary drilling report and a preliminary geologic report, are in preparation.

2. Field work during the 1953 season will be designed to check the tentative additional reserves in the lake flats and in the southern part of the area by core drilling and augering; to check the potentially important uranium-bearing coal beds underlying "gravels" on the continental divide in the vicinity of Creston; to investigate potential deposits in the Bison Basin area, 40 miles north of the mapped area; and to relate the mapping to previously published maps of areas to the south and northwest.

Fall Creek area, Bonneville County, Idaho
by J. D. Vine

Field work in the Fall Creek area, Bonneville County, Idaho, was undertaken during the 1952 field season to determine the areal extent, thickness and grade of the uranium-bearing strata in the Cretaceous Bear River formation. The only previously known occurrence was at the Fall Creek coal prospect in NE$\frac{1}{4}$ sec. 4, T. 1 S., R. 42 E.

The stratigraphic relations of the Jurassic and Cretaceous formations were studied and an area of about 40 square miles was mapped on aerial photographs at a scale of 1:20,000. Approximately one hundred samples were collected during the past field season from the uranium-bearing strata and have been submitted for analysis.

Reconnaissance studies were conducted in the Caribou Mountains and adjacent regions, which surround the Fall Creek area, to determine the areal extent of the Bear River formation and the possible continuity of the contained uranium-bearing strata. The Bear River formation was examined and samples were collected for analysis from widespread localities and mild radioactivity was detected at many places though nothing was found comparable to the deposit at the Fall Creek coal prospect (TEM-340). Within the Fall Creek area the known distribution of uranium-bearing strata has been greatly extended and the estimated reserves correspondingly increased (table 3). The uranium-bearing carbonaceous rocks of the Fall Creek area are a potentially valuable reserve of uranium and worthy of continued effort to determine the size and grade of the deposit. The lack of good exposures make core drilling necessary to determine the areal extent, thickness and grade of the deposit.

Table 3.--Estimated reserves _/ of uranium in the Fall Creek area, Idaho

Block one

Rock type	Tons/acre foot	Size of area	Thickness of rock unit	Uranium (percent)	Rock (tons)	Uranium (tons)	
Limestone	3,600	57 acres	1.5 feet	0.02	308,000	61.6	
Carb. sh.	2,600	57 acres	1.5 feet	0.024	222,000	53.3	
Coaly sh. (top)	1,750	57 acres	1.0 feet	0.045	99,800	44.9	
Coaly sh. (base)	1,750	57 acres	3.0 feet	0.011	299,000	33.0	
					928,800	192.8	Sub-totals
Block two							
Limestone	3,600	54 acres	1.5 feet	0.02	292,000	58.4	
Carb. sh.	2,600	54 acres	1.5 feet	0.024	211,000	50.6	
Coaly sh. (top)	1,750	54 acres	1.0 feet	0.045	94,500	42.5	
Coaly sh. (base)	1,750	54 acres	3.0 feet	0.011	284,000	31.2	
					881,500	182.7	Sub-totals
Block three							
Limestone	3,600	356 acres	1.5 feet	0.02	1,920,000	384	
Carb. sh.	2,600	356 acres	1.5 feet	0.024	1,390,000	334	
Coaly sh. (top)	1,750	356 acres	1.0 feet	0.045	623,000	280	
Coaly sh. (base)	1,750	356 acres	3.0 feet	0.011	1,870,000	205	
					5,803,000	1,203	Sub-totals
				Totals (rounded)	7,600,000	1,600	

_/ Estimated reserves are commonly classified according to decreasing order of probability by use of the terms: measured, indicated and inferred. However, these terms are not applied here because it is believed that an even lower order of probability is represented by the estimates listed above.

Slim Buttes area, South Dakota
by J. R. Gill

Drilling in the Slim Buttes area, Harding County, S. Dak. was begun in October at the request of the Commission. The Geological Survey is logging the core holes and on completion of the drilling will prepare a report on the uranium resources indicated by the drilling, the coal reserves in the ground, and the geology of the area. As of the end of November, 9 of the projected 34 holes had been completed. It is understood that the drilling will continue until closed down by weather, and be resumed next spring to complete 10,000 feet of drilling before June 1. Reports will be prepared as soon as analyses are available.

Coyote Mining district, New Mexico
by H. D. Zeller

Geologic mapping at a scale 1:12,000 has been completed for the Coyote mining district near Guadalupita, Mora County, N. Mex., where uraniferous copper deposits were found in 1951 (Bachman and Read, 1951). Many new uraniferous copper showings were found in a sequence of shale, carbonaceous shale, and arkose. It is not possible to establish average grades for individual prospects or the area as a whole. A very subjective estimate is that significant tonnages of material containing perhaps 0.05 percent uranium and 2 to 4 percent copper may be present. Physical exploration will be necessary to evaluate the potentialities of the deposit and plans are being made for presentation to the Commission.

Chattanooga shale investigations
by L. C. Conant

The specific objectives of the 1952 field work were: (1) To collect samples from Chattanooga shale outcrops, spaced about 5 miles apart, along the northern edge of the Nashville Basin in Tennessee from Macon County to the vicinity of Nashville; along the Cumberland River and several scattered inliers in southern Kentucky; and, at a greater spacing, in scattered outcrop areas in Tennessee, northern Alabama, and northwest Georgia. (2) To study in detail the outcrop of the Chattanooga shale in an area in east-central DeKalb County, Tennessee, where previous study has indicated somewhat higher uranium concentration. These objectives were accomplished during the field season June 10 - October 10, 1952, and thus brought to completion most of a program inaugurated in 1947 but largely curtailed in 1948.

During the field season, 807 samples were taken for uranium assay--776 from the Chattanooga shale and 31 from the overlying Maury formation. Of the 807 samples, 120 are special samples collected to obtain more detailed information on the distribution and mineralogic associations of the uranium within the Chattanooga shale. The remainder are routine channel samples.

The average weight of most of the samples taken was about 4 pounds, each being a crude channel sample of a 1-foot interval of black shale. These samples, with some unavoidable exceptions, were of fresh or only slightly weathered shale. Most were taken from roadcut outcrops, using pneumatic equipment and ordinary geologic hammers.

A map showing the locations of the 55 outcrops sampled, was submitted with TEM-553, "Chattanooga shale investigations" by V. E. Swanson.

A summary of the outcrops studied and sampled during 1952 field season is listed below:

	Tennessee	Kentucky	Alabama	Georgia	Total
Number of outcrops visited and described	83	11	13	1	108
Number of outcrops sampled	38	7	9	1	55
Number of samples collected	579	123	100	5	807

At the time this report is written very few assays have been received; hence any conclusion drawn now on uranium distribution is tentative and preliminary. From the few assays in hand, however, and in light of all known lithologic evidences of uranium concentration in the Chattanooga shale, unreliable as they probably are, it seems unlikely that any area studied in 1952 will prove of greater economic interest than the Block 1 area in DeKalb County, Tennessee.

Assays of selected Chattanooga shale samples from the Nashville area averaged about 0.0045 percent uranium. This nullifies a suspicion, based on lithologic characteristics, that the uranium content there might be as high as in DeKalb County.

The high uranium assay of a Chattanooga shale sample (a single phosphate nodule) from Marion County, Kentucky, submitted by a private citizen, instigated the systematic sampling of several outcrops in that area. Assays received confirm earlier conclusions that the average uranium content of the shale on the southern edge of the Lexington Basin is on the order of 0.003 percent.

Plans

A report, "Uranium content of Chattanooga shale in several parts of Tennessee and adjacent States," based on the findings in 1952, is now in preparation. In addition to providing further information on the regional and stratigraphic distribution of uranium in the Chattanooga shale in Tennessee, southern Kentucky, and northern Alabama, it is hoped that careful analysis of all assay data will yield new information on 1) the effect of weathering on uranium content, 2) uranium concentration in specific materials, and, 3) vertical and lateral variations of uranium concentration within short distances.

At the request of the Atomic Energy Commission, arrangements have been made to provide geologic guidance during the drilling program to be carried out by the U. S. Bureau of Mines near the Sligo area in DeKalb County, Tennessee. Mr. Thomas M. Kehn, who was a member of last summer's field party in Tennessee, has been assigned this job under the supervision of L. C. Conant. Mr. Kehn will take charge of all cores of the Chattanooga shale, prepare detailed lithologic logs, and split the cores for assay samples, and for special mineralogic and paleontologic studies.

In addition, Mr. Conant and Mr. Kehn will be available to serve in an advisory capacity to predict depths to key units during drilling and provide other geologic information that may be needed. At the conclusion of the drilling a report will be prepared summarizing the uranium content of the Chattanooga shale in the area drilled. This report will present the assay data, give the average uranium content of the beds, and show the calculated tonnage of uranium.

Organic matter of the Chattanooga shale
by J. M. Schopf

The investigation of the organic matter in the Chattanooga shale was undertaken at the request of L. C. Conant and W. M. Monroe, who have continued extensive studies of the Chattanooga shale under Survey and Commission support, for the past several years. The object of this study is to bring the special qualifications of the paleobotanist and coal petrographer to bear on what is perhaps the most characteristic, but most enigmatic, feature of these distinctive deposits. A preliminary report is now in preparation which indicates the nature and sources of organic matter more fully than has been possible before.

Limited material has been available from Tennessee, Indiana, Ohio and New York with ancillary paleobotanical materials obtained from other states. These have been studied by means of thin sections, macerations and other regular methods of paleobotanical investigation. In addition some selected organic matter has been specially prepared for chemical analytic determinations.

The bulk of the organic material in the black Chattanooga shale consists of a marine type of humic matter so finely decayed and shredded that specific and direct determination of its plant source is impossible. Its origin must be inferred from the sporadic associated occurrences of fossil plants that are capable of identification and are of such a nature that they could contribute this type of organic debris. Among such plants are examples of megaplanktonic marine algae, members of the Foerstiales, of which four species can be identified. Drift wood of Callixylon, an unquestioned land plant, is widely represented. Apparently a large marine alga, Protoaxites, of littoral habitat, is present in some material. The most abundant fossils are spore-like in form (but unlike any known land-plant spores in details of their construction) that are best identified with the form genus Tasmanites. These include the forms that commonly have been called "sporangites" in previous literature. Although their plant origin cannot now be proved, they evidently have marine ecologic significance. Even when counting the abundant Tasmanites microfossils, the identifiable elements of the assemblage do not account for 5 percent of the organic matter; unidentifiably humic debris may vary in the more highly organic laminae from 20 to 50 percent.

Thin sections of selected portions from the black shales show the relationship of organized fossils to the more finely degraded debris and illustrate the great variation in organic content of the more or less alternating lamellae. The texture of the inorganic detritus does not vary nearly so much as the organic concentrations which disperse the mineral grains. One might infer that non-preservation of organic matter is a primary cause for mineral rich laminae in the black shale. In some instances where contacts are gradational and irregular this is almost certainly the case, but there is reason to doubt whether this explanation is always applicable. For example, well preserved thalli of Foerstia commonly are almost restricted to the mineral rich bands and only occasionally occur in the organic layers. Disseminated micro-crystals and aggregates of pyrite, indicative of anaerobic decay, are observed in both kinds of lamellae. Calcite, some of which evidently is secondary, is most common in the mineral rich layers. Presumably this is a function of greater porosity. The organic layers are much more dense and evidently highly impermeable. Scattered but persistent greenish mineral particles, presumed to consist of glauconite, can be found both in organic and mineral rich lamellae. Quartz is the most abundant mineral among the silt-size particles. It is difficult to estimate the quantity of clay in organic layers since humic stain can so easily obscure it. The clay content of mineral rich layers is not very great and it may be that a larger proportion of organic layers is actually clayey. However, the larger humic particles are sufficiently abundant to indicate that clay is rarely the dominant constituent of the black laminae of the rock.

"Spores" of Tasmanites are frequently present in both types of laminae. They are now more abundant in the organic bands but, in terms of original deposition, a comparable estimation is difficult owing to the very considerable amount of post-depositional compaction of the organic layers. Several kinds of Tasmanites have been distinguished, among them one variety with a multilayered wall that apparently was last reported by P. F. Reinsch (Micro Paleo Phytologia) in 1883. Intergradational forms are present in most instances so that an informal "type" classification may now be advisable. Mineralized "spore" forms showing faithful preservation of original form and features have been of material assistance in distinguishing corroded and well preserved compressed examples as they normally occur in the shale.

Future plans are to complete an illustrated account of the various materials now on hand as soon as possible. Later work extending these observations should be carried on so that a better quantitative estimate can be made of the geographic variation in organic matter in this widespread formation. The general correlation of uranium and organic matter in the black shale seems well established although the relationship probably is also dependent on additional factors. Some approach can be made to this problem utilizing stripping films to obtain specific qualitative data.

The opportunity to extend these studies may depend on the progress of other investigations that can be relied upon to supply suitable materials, as well as upon the actual time that can be spared from other unrelated duties. A more complete account will be submitted in June 1953.

Core processing
by J. M. Schopf

The Survey's Coal Geology Laboratory at Columbus has been responsible for preparing detailed records and sampling all sections of core shipped by field geologists. This work is important because all further research depends on having available, adequate records and samples suitable for several different kinds of study. The basic data resulting from core processing have been made available rapidly to all scientists directly concerned with drilling programs. After receipt of the core shipments at Columbus, processing reports usually are sent within a week to the field, analytic, and administrative offices. The steps involved in "core processing" are given below.

1. Liaison with operating field geologist about methods of marking and shipment of coal cores to safeguard coal analytic values.

2. Detailed description of cores; preparation of full-scale log strip showing breakage, loss in drilling, character and relationship of portions actually recovered.

3. Selection of sample intervals for (a) trace elements determinations and (b) coal analytic determinations. Sample intervals are recorded on full-scale log strip.

4. Machine cutting of core into sample and reserve portions; crushing and riffle splitting of equivalent portions, where both coal samples and trace elements samples are taken from the same sections of core.

5. Determination of preliminary radiometric values of short core sections for all portions of cores received, as a check guide for sampling and to indicate appropriate analytic requests.

6. Preparation of detailed processing report, giving description, sampling intervals, radiometric results, core condition and analyses requested; preparation of graphic summary and radiometric chart, 1/20 scale, showing lithologic and radiometric relationships; distribution of reports to scientists concerned.

7. Preparation of analytic request lists for Trace Elements Washington Laboratory, and for the Coal Analysis Section, U. S. Bureau of Mines; preparation of samples for shipment and transmittal of sample information.

Steps 2, 3, 4, and 5 must proceed concurrently and rapidly because the cores are received in a wet condition and samples of coal that has dried out, even slightly, are not suitable for petrographic studies. Coal samples thus require particularly prompt handling to prevent drying. Coal analysis reports for each drill hole are returned from the Bureau of Mines to the Coal Geology Laboratory; copies of these reports are then distributed to all of those who originally received core processing reports. Analytic reports of the Trace Elements Washington Laboratory, when available, are distributed through the Fuels Branch Office in Washington to Coal Geology Laboratory and Project Geologists.

The results of core processing activities at the Coal Geology Laboratory for Dakota and Red Desert drilling can be summarized quantitatively, as follows:

1. Core processed: about 585 linear feet.

2. Radiometric determinations reports: about 980.

3. Individual samples submitted for uranium determinations and spectrography: 761.

4. Individual coal samples submitted for analysis: 90.

5. Individual reports on laboratory processing: 41.

This work has been accomplished in spite of a general lack of pre-trained assistants and relatively rapid turn-over of part-time employees. It is hoped that these sources of difficulty have been overcome for the future.

The purpose of the core processing program is to sample the cores effectively and to prepare, as rapidly as is practical, a consistent and objective record for general reference by field and laboratory scientists engaged in research on these materials. Owing to the large numbers of samples that are involved in this and other programs, some delay occurs in obtaining Bureau of Mines and Trace Elements analyses. For this reason the processing reports including radiometric values have considerable significance for early estimation of results.

Radioactivity measurements are prepared in the Coal Geology Laboratory from coarsely crushed samples (minus $\frac{1}{4}$ inch) and may be subject to greater error than if the samples were homogenized. However, a rapid relative comparison of samples is more desirable at this stage than absolute accuracy. These measurements are expressed as "pulses per minute per gram" (P/M/G), to distinguish them from values obtained by more accurately calibrated radiometry, but attention has been given to the degree of correlation between P/M/G results and chemically determined amounts of uranium in 90 samples from the Slim Buttes area for which both P/M/G and chemical determinations are available. These are summarized on figure 13.

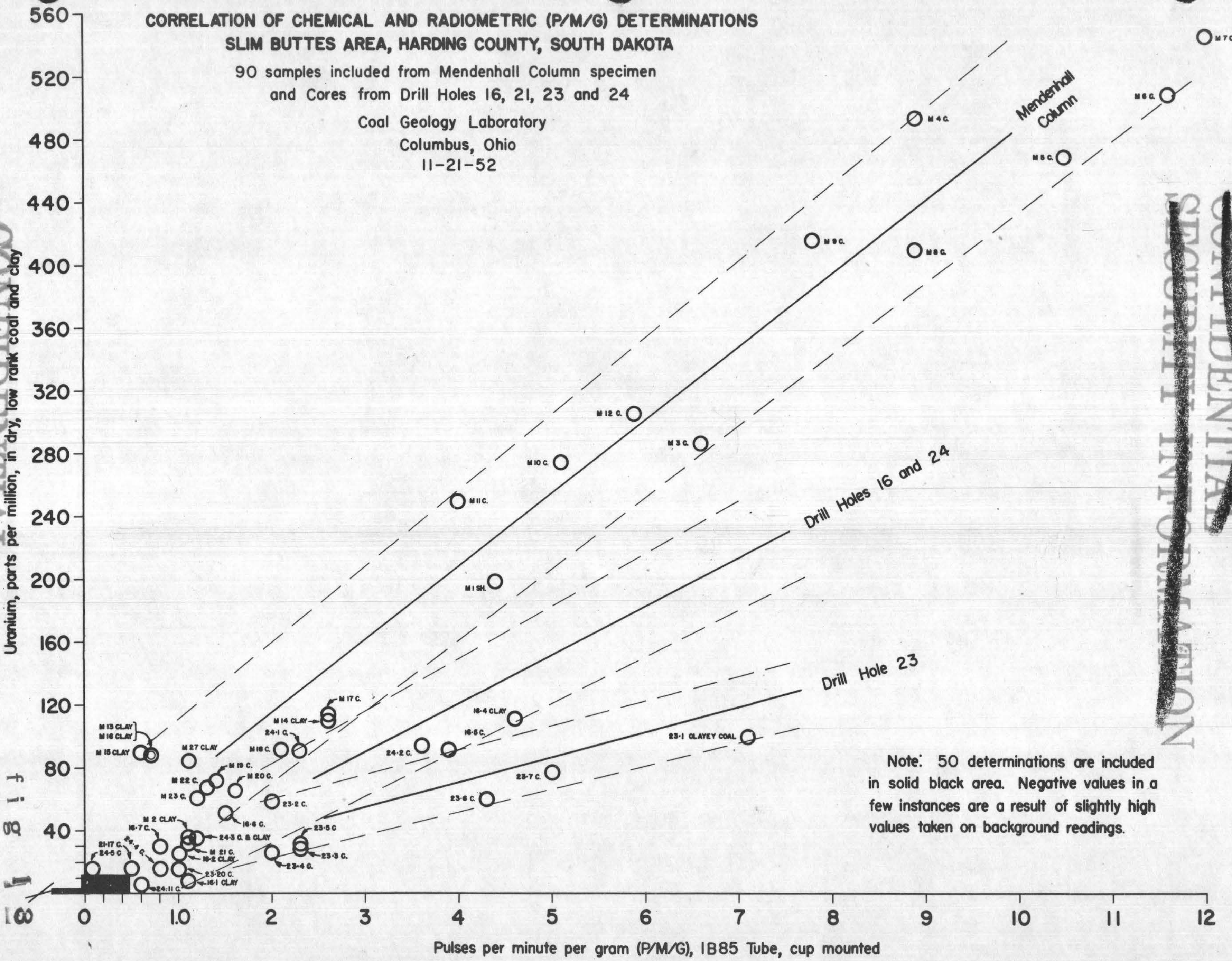
It appears from the plotting of P/M/G values against parts per million uranium (.0000%) that three different correlation levels exist. The dashed lines in figure 13 are drawn to include all samples in each of the three different levels. If it is assumed that the mid-line in each instance approximates an ideal correlation, with errors in radiometric and chemical measurement accounting for the widths between the dashed lines, it would seem that for Mendenhall samples P/M/G numbers should be multiplied by about 48 to approximate the parts per million of uranium; for samples from holes 16 and 24 P/M/G values should be multiplied by about 30; for hole 23 the closest approximation to parts per million uranium would be obtained by multiplying P/M/G values by about 17.

Probably these data are capable of much more precise analysis, but it seems evident from this that we can assume a reasonable degree of <u>relative</u> consistency for the P/M/G values obtained by our rapid methods on successive samples from individual core holes. Perhaps later on a uniform ratio can be established. For the present the P/M/G values are believed to have relative accuracy **but they should <u>not</u> be translated into terms**

CORRELATION OF CHEMICAL AND RADIOMETRIC (P/M/G) DETERMINATIONS
SLIM BUTTES AREA, HARDING COUNTY, SOUTH DAKOTA

90 samples included from Mendenhall Column specimen and Cores from Drill Holes 16, 21, 23 and 24

Coal Geology Laboratory
Columbus, Ohio
11-21-52



Note: 50 determinations are included in solid black area. Negative values in a few instances are a result of slightly high values taken on background readings.

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of absolute uranium content.

An effort has been made not only to prepare accurate detailed reference data in our processing reports but also to present the most important data in diagramatic summary so that the major results can be easily appreciated. These charts give indication of the major variations in lithologic character and a graphic representation of P/M/G values. Figure 14 includes two of these diagrams based on series of samples for which the relative accuracy of the samples has been thoroughly established.

Plans

Cores of coal and associated rocks will continue to be processed to obtain accurate samples for analysis and reserve portions suitable for future research. The present general plan of operation seems adequate but an effort will be made to systematize this work so that it may proceed more efficiently.

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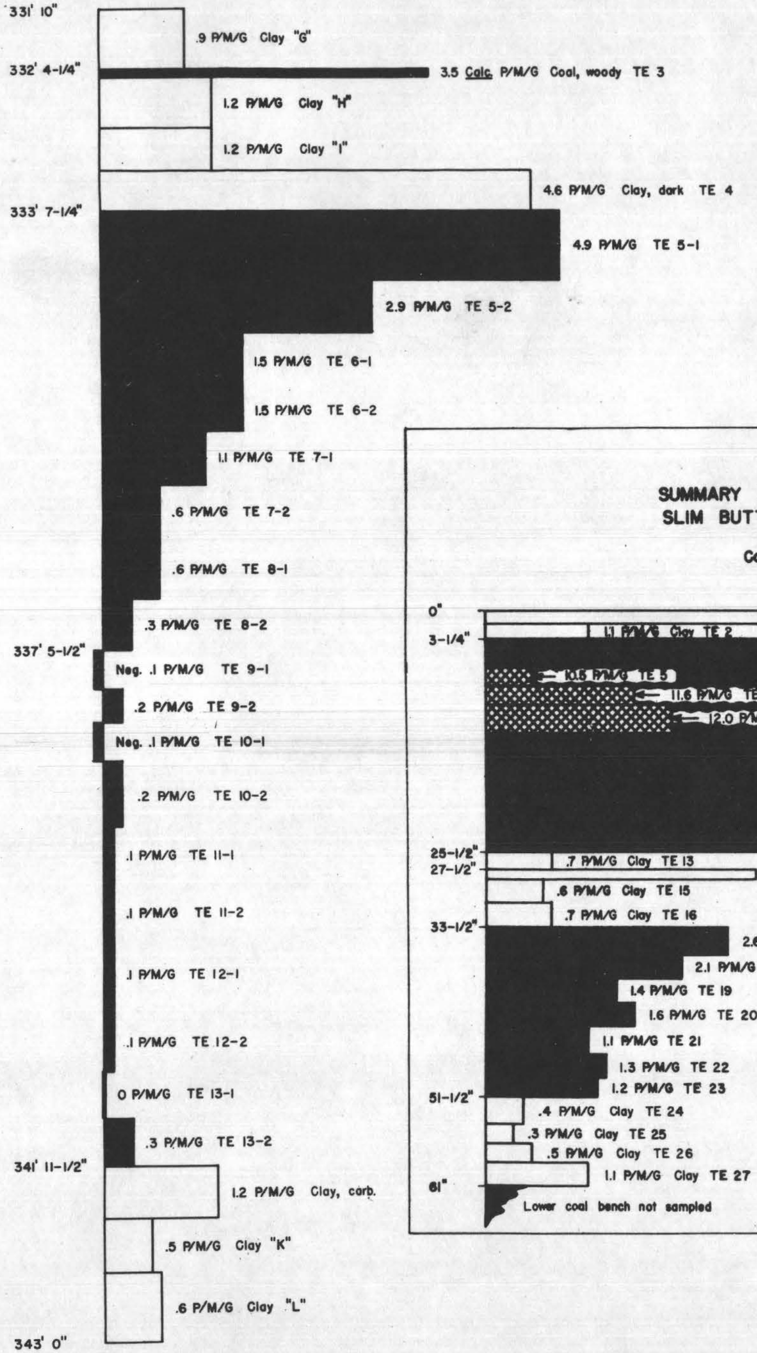
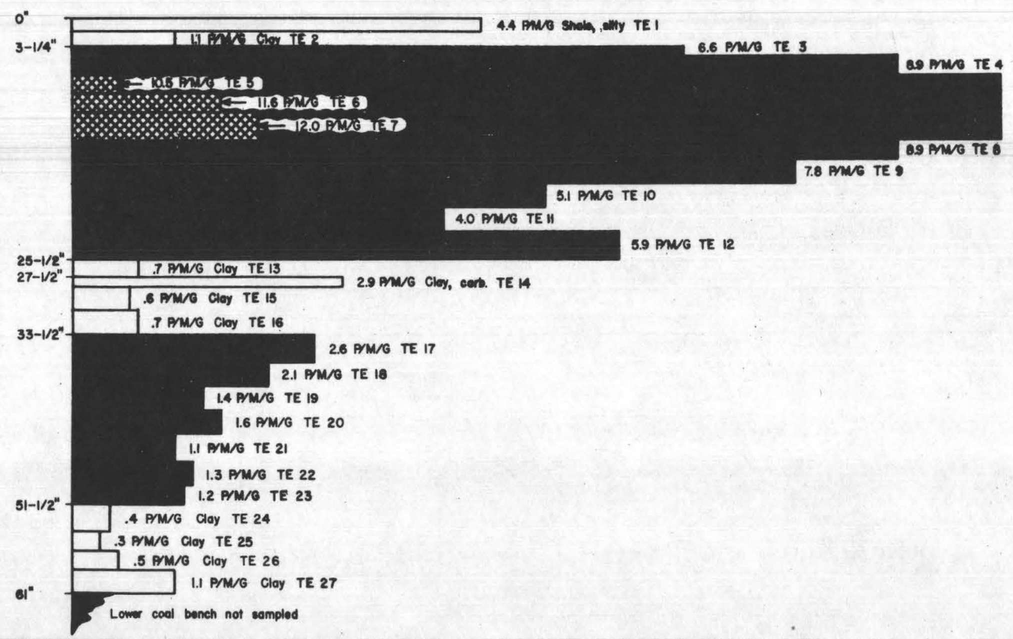
fig 14

SUMMARY P/M/G RESULTS HOLE 16 (MENDENHALL COAL BED)
SLIM BUTTES AREA, HARDING COUNTY, SOUTH DAKOTA
Project 469 WF-AEC
Coal Geology Laboratory, Columbus, Ohio 11-25-52
Coal shown in black



SUMMARY P/M/G RESULTS MENDENHALL COLUMN SAMPLE
SLIM BUTTES AREA, HARDING COUNTY, SOUTH DAKOTA
Project 469 WF-AEC
Coal Geology Laboratory, Columbus, Ohio. 11-25-52
Coal shown in black



SEARCH FOR AND GEOLOGY OF URANIUM IN PHOSPHATE

Northwest phosphate
by R. W. Swanson

Studies of the Northwest phosphate project have included a comprehensive investigation of the western phosphate deposits and the stratigraphy of the Phosphoria formation and geologic mapping of the equivalent of about 10 15-minute quadrangles, plus associated studies of paleontology and geochemistry. During the summer of 1952 the Phosphoria formation was described and sampled from hand and bulldozer trenches and mine exposures at six localities in southwestern Wyoming, thereby rounding out our information in this part of the field and concluding the organized sampling program. Some 280 samples were collected and about 2000 feet of strata were described, raising the projects' totals to about 9000 samples and more than 35,000 feet of stratigraphy.

The principal developments as a result of this work in southwestern Wyoming are a clarification of critical stratigraphic correlation in this part of the western field and discovery at one locality, Basin Creek, of a 12½-foot bed of low-grade phosphate at the top of the upper shale member, just below the Dinwoody contact. This bed was correlated over a fairly broad area but nowhere else was it as much as 3 feet thick. Further reconnaissance in the area indicates that the thick phosphate is probably very local. Sample analyses show 12.7 feet of 20.0 percent P_2O_5 rock that contain only 0.002 percent equivalent uranium. At the top of the main phosphatic shale member is a zone 3 feet thick that contains 33 percent P_2O_5 and 0.10 percent uranium or 11 feet thick that contains 24 percent P_2O_5 and

0.006 percent equivalent uranium. No other phosphate beds as rich or thick were found this summer though minable thicknesses of furnace-grade rock (25 percent P_2O_5) appear to have been found at one or two localities (analyses of samples are not yet complete).

Geologic mapping activities this year were much smaller than in previous years, due to previous completion of field work or other demands on geologists' time, such as sampling and DMEA work. But the mapping of two 7½-minute quadrangles was completed by G. C. Kennedy in Montana--south half of SW¼ Lyon--and the Johnson Creek and Dry Valley 7½-minute quadrangles in Idaho were reviewed prior to submission for publication by R. A. Gulbrandsen and E. R. Cressman. Compilation of columnar section and land ownership data has been continued at a steady pace and two more reports of analytical data are in preparation.

Plans for the remainder of the winter office season include chiefly compilation of columnar section, analytical, and mapping project reports for publication. Plans for next field season include: (1) some spot sampling in areas of critically needed information, such as near Blackfoot Reservoir in Idaho and Philipsburg, Maxville, and Elliston in Montana where our information is weak but where valuable phosphate deposits are known to occur; (2) correlation studies based chiefly on stratigraphic information already assembled; (3) some reconnaissance into unexplored parts of the field, such as northeastern Nevada and north-central Wyoming; and (4) continuation of geologic mapping in the Aspen Range-Dry Ridge area of Idaho and the Lyon quadrangle of Montana.

Southeast phosphate

Geologic studies
by J. B. Cathcart

Geologic work in the half-year ending November 30, 1952 consisted of stratigraphic studies of the Hawthorn formation, the Alachua formation, the Bone Valley formation, and the surficial sands; chemical studies of weathering, the relation of uranium to P_2O_5, Al_2O_3, and other elements; sedimentary studies, including heavy mineral, and insoluble residue analyses; structural studies; and studies of the origin and distribution of the phosphate and uranium.

Stratigraphic studies

The Hawthorn formation.--The Hawthorn formation, of middle Miocene age (MacNeil, 1947) crops out in Florida, Georgia, and South Carolina, and is present in the subsurface of these states.

The Hawthorn formation consists of limestone, dolomite, sands, and clays, all of which contain variable amounts of phosphatic nodules. The Hawthorn formation is the source of much of the economic phosphate in the land-pebble and hardrock districts of Florida, and the phosphate deposits of South Carolina. Therefore, a study of the Hawthorn formation, its stratigraphy and distribution, is of considerable importance in determining the mode of origin of the phosphate deposits and their included uranium.

The stratigraphy of the Hawthorn formation has not been extensively investigated. Lack of exposures in the coastal plain makes it impossible to see much of the formation. As exposures are generally only a few feet thick, no type section has been described, and therefore cuttings from deep wells must supply the type section.

The sections of the Hawthorn formation are very different, even in Florida. General stratigraphy in the land-pebble district of Florida is as follows: at the base, a cream-colored, sandy and clayey limestone, next a series of sands and clays, and at the top, a fossiliferous dolomite (TEI-212, Cathcart and Davidson). All of these rocks contain nodules of phosphorite. The P_2O_5 content varies from 9.8 to 35.0 percent and averages 22.7 percent.

Drilling in South Carolina showed that the Hawthorn formation (in the areas drilled) consists principally of dark to greenish-gray to tan sandy or silty clay, containing black, brown, amber, white and gray phosphate nodules. The P_2O_5 content of the nodules varies from 1.9 to 35.9 percent, and averages 20.3 percent. The phosphate nodules are all well rounded and have a high polish. Many of the coarse nodules are phosphatized molds and casts of invertebrate fossils. A few random analyses of this phosphate show a content of 0.010 to 0.030 percent uranium. Several samples have been taken recently and are being analyzed.

The Hawthorn formation in Georgia, as shown by shallow drilling, is similar to that in South Carolina, except for color. In Georgia it consists of gray or greenish sandy clays and clayey sands containing phosphorite nodules. The nodules are quite similar in physical characteristics to those in South Carolina and Florida. The Hawthorn formation in northern Florida consists of light and dark gray sandy clay and clayey sand which weathers to reddish and white mottled clayey sand.

Seas covered most of peninsular Florida, eastern Georgia and South Carolina during the deposition of the Hawthorn formation. In western Florida the Hawthorn formation was deposited in a deltaic and continental rather than a marine environment (Vernon, Fla. Geol. Surv. Bull. 33, 1951). The Hawthorn formation was probably deposited as the Ocala uplift was rising. It is much thinner over the Ocala uplift and is missing entirely in some areas.

The thickness of the Hawthorn formation varies from a feather edge at the northern end of the land-pebble phosphate district in Florida to a maximum of perhaps 500 feet in deep wells in northern Florida. In Georgia, the Hawthorn formation is about 300 feet thick near the Florida line, but thins gradually to the northeast. (Cooke, USGS Bull. 941, 1943, pp. 89-91) In South Carolina, (Cooke, USGS Bull. 867, 1936, pp. 101-104) the maximum recorded thickness is 160 feet.

Because the State Geological Survey at Tallahassee has a rather complete cuttings library from deep wells drilled in Florida, the first step in unravelling the stratigraphy of the Hawthorn formation is to carefully log these deep wells and attempt to establish a type section, or if that is not possible, a series of type sections for the formation. This work is currently being carried on by a student at Florida State University at Tallahassee, and he will continue to work about 1/4 time for the remainder of this fiscal year.

Samples of the Hawthorn formation will be taken with the jeep-mounted Mobile drill in an attempt to find out more about phosphate in the formation.

In the land-pebble field the relations between the Hawthorn and the overlying Bone Valley formation are being studied. This work will include chemical and heavy mineral studies as well as physical relations.

Insoluble residue studies on the Hawthorn are also being carried on by D. C. Alverson.

The Alachua formation, by K. B. Ketner.--Concentration of study upon the Bone Valley formation or small areal or stratigraphic parts of it may lead to lack of perspective and erroneous conclusions in the solution of geologic problems. Problems might be more easily solved if more were known about other phosphatic lithologic units in Florida such as the Alachua, Hawthorn, and Buckingham formations. Preliminary study has brought out an essential unity among these formations. All consist of part of the following sequence of strata or zones:

Zone	General lithology
A	Massive, loose quartz sand
B	Massive quartz sand loosely cemented with clay and/or aluminum phosphate
C	Massive or bedded quartz sand, clay, and apatite
D	Limestone containing quartz sand, clay, and apatite

According to accepted usage the Hawthorn formation consists of zones B, C, and D, whereas the Alachua, Bone Valley, and Buckingham formations consist of B and C although the other zones are usually present. The Buckingham marl has not been seen by the author, but published descriptions (Parker and Cooke, Fla. Geol. Surv. Bull. 27, 1944, p. 59) indicate that it belongs in this group.

A study of the Alachua formation was undertaken in August 1952 in an attempt to explain in detail the similarities and differences between it and the Bone Valley formation, and to solve the problems common to both. A reasonable knowledge of the Alachua formation requires investigation of the following problems:

1. Mineralogy of the formation

2. Areal limits of the formation

3. Age and origin of the formation

4. Principles governing the genesis and distribution of high-grade phosphate within the formation

Work on mineralogy has begun. In general, it is similar to that of the Bone Valley formation. Samples are being studied, but details are not yet available because of a lack of adequate numbers of X-ray and chemical analyses of fine-grained material.

The areal extent has been found to be considerably greater than geologic maps indicate. It is difficult to delineate the Alachua because of a lack of a clear conception of the Alachua as a lithologic unit. In the Croom-Dade City area, for example, exposures of sediments mapped as the Hawthorn formation appear to be identical to exposures of those mapped as Alachua. Detailed mineralogical and sedimentary studies may be necessary to bring out essential differences, if any exist.

Three hypotheses of origin are being considered:

1. Residual concentration by weathering of a pre-existent blanket of Hawthorn limestone.

2. Residual concentration by the pre-Hawthorn Tampa, Suwannee, or Ocala limestones.

3. Sedimentation in an aqueous environment.

The possibility of complex origin involving 2 or more processes is not overlooked. It might be suggested that the Alachua was formed through a process of replacement of underlying limestone by descending solutions carrying phosphate from beds of guano or other sources. This hypothesis cannot be generally valid for the formation as a whole because the underlying limestone contains less than 1 percent of clastic quartz sand (in some places a minute fraction of 1 percent), but the Alachua, based on information from several scattered mines, contains 5 to 75 percent of clastic quartz sand. Some "plate rock" phosphate which thinly encrusts bedrock limestone in places may be of replacement origin.

There is little direct evidence that the Hawthorn limestone once covered the area now occupied by the Alachua formation. Moreover, the Hawthorn formation is characterized over a wide area by nodular phosphate, and if weathered would tend to form a residue containing apatite nodules similar to the Bone Valley formation rather than a residue containing massive clay-like apatite such as the Alachua formation.

The pre-Hawthorn limestones contain phosphate, clay, and quartz sand, and under severe weathering could form a residual mantle similar to the Alachua formation, but these "impurities" form such a small part of the limestones that the solution of strata hundreds or thousands of feet thick would be required to yield a residuum equal to the Alachua formation in thickness.

Hypotheses involving aqueous transportation and deposition of the Alachua formation in a continental or marine environment are not convincing. They do not satisfactorily explain the zonation and the "karrenfeld" or pinnacled bedrock contact, the notable lack of bedding, or the formation's relationship to the Ocala uplift.

A method of attacking the problem of origin has been developed which promises some success. Although evidence of weathering is abundant throughout the Alachua formation, it is certain because of its insolubility that the quartz sand, which is universally present in all zones as a primary constituent, has not been taken into solution by underground water to any appreciable extent. This cannot be said of any other principal constituent. Therefore series of channel samples from bedrock to surface are being collected from several localities and the quartz sand contained in each is being isolated by a combination of acid leaching and washing. Comparisons are made between sorting patterns of quartz samples from different zones in the same section. For example, table 4 shows the sorting patterns of quartz sand in samples from a mine at Croom. The sorting pattern of the top sample of zone B is nearly identical to that of zone A. The supposed reworking which, according to accepted theories, resulted in the removal of the non-quartz fraction of zone A in Pleistocene time is not evident from the quartz sorting pattern. On the other hand there is a distinct break in the sorting pattern between zone D and the lowest sample of zone C indicating, if proved to be typical, that the Alachua formation is probably not a residuum derived from limestone similar to that which presently underlies it.

A review of published paleontologic evidence bearing upon age and origin is in progress. Most fossils of the Alachua formation, like those of the Bone Valley formation, are Pliocene or Miocene in age, but uncertainties surround the collection, identification, and dating of many of these fossils.

The mode of concentration of phosphate to commercial or near commercial grade in parts of zone C of the Alachua formation is under investigation, but no conclusions can be made as yet.

Table 4.--Size analysis of +200 mesh quartz sand in a series of channel samples from bedrock to surface at the Buttgenbach mine, Croom, Florida.

Zone	Sample number	Percent of +200 mesh quartz fraction					
		+40	+50 -40	+70 -50	+100 -70	+140 -100	+200 -140
A	68	4	9	42	29	13	3
B	67	4	9	45	29	11	3
	66	4	16	50	21	8	1
	65	4	12	45	24	11	3
C	64	12	15	26	24	16	7
	63	8	12	26	26	19	10
	62	14	17	31	24	11	3
	61	2	1	5	18	44	30
	60	2	2	4	13	46	34
	59	0	0	1	4	52	43
D	58	2	4	19	29	33	13

<u>The Bone Valley formation</u>, by M. H. Bergendahl and C. H. Gray, Jr.--In order to delineate more clearly the boundaries of the land-pebble phosphate field and to obtain more complete stratigraphic data on the relationships of the Bone Valley formation with the Citronelle, Caloosahatchee, Alachua, Suwannee, and Tampa formations, a program of geologic drilling has been proposed. (Cathcart, TEI-212, 1952)

Proposed holes have been located, and recommendations have been made to the AEC with respect to the provisions of a drilling contract.

The southern boundary of economic phosphate in the Bone Valley formation is incompletely known, and information regarding the southward extent of the entire Bone Valley formation is inadequate.

Since the entire area is covered by Pleistocene sands this work is necessarily dependent upon drilling. In the recent past the phosphate mining companies have done little active exploration south of the Polk-Hardee County line, since prospecting information has shown that economic "matrix" does not extend southward from this line, except perhaps in localized areas. However, phosphate-bearing sandy clays extend southward for another 25 to 35 miles before the Bone Valley merges with the Caloosahatchee marl, which contains some phosphate particles. In this area more exploration is required to determine the limits of economic phosphate and the relation of the Bone Valley formation to rock units to the south.

An opportunity to study the relations of formations bordering the southern edge of the phosphate district was presented recently when the Continental Oil Company began an extensive, long term, geophysical prospecting program in this area. The company has been most cooperative in every regard and has allowed personnel of the U. S. Geological Survey to sample the holes drilled, and to make lithologic logs. Drilling has been done only in the southeastern part of DeSoto County, well within the outcrop of the Caloosahatchee marl.

The holes show from 20 to 25 feet of unconsolidated sand; 75 to 80 feet of a greyish-green sandy clay with thin layers of shell fragments; and at depths of more than 100 feet below the surface, a hard limestone. The latter is apparently composed of an alternating series of hard limestone with little sand and a soft limestone with considerable sand.

Sparse black phosphate pebbles and sporadic fine black phosphate are found in each of the foregoing units, except the unconsolidated sands. The surficial sands are probably Pleistocene; the lithologic character of the greyish-green sandy clay appears to correspond with the Pliocene Caloosahatchee marl, as described by Cooke (1945); and the phosphatic sandy limestone is probably the middle Miocene Hawthorn formation also described by Cooke (1945). Unfortunately these holes are too far south to be of any great value in determining the southern extent of the Bone Valley formation.

<u>Stratigraphic studies of mine face samples</u>, by R. G. Petersen.--Marked differences appear in the chemical composition, quantity, and size distribution of the phosphate in the mines of the land-pebble district, even though only a few tens of miles may separate the mines. The purpose of the work for this report is to find exactly what these differences are and to attempt to explain the reasons for them.

Complete sections are being described and samples taken of every lithologic unit from the Hawthorn limestone to the surface sand from several of the mines in the district. At present, samples from two mines, Achan and Pauway, have been disaggregated and screened. A mechanical analysis has been made and each size fraction has been treated in bromoform (diluted to sp. gr. of 2.75) to separate the quartz from the phosphate and heavy minerals. In the next separation step, methelene iodide (diluted to sp. gr. of 3.00) was used to separate most of the phosphate from the heavy minerals.

In the methelene iodide heavy fractions that still contain a large amount of "heavy" phosphate, a Frantz Isodynamic separator will be used to remove the nonmagnetic "heavy" phosphate. The identification of the clay minerals in the -200 mesh fractions will be made with the help of an X-ray spectrometer.

A chemical analysis will be made of each of the phosphate fractions to determine what differences exist in the chemical composition of the phosphate with respect to the specific gravity, position in the section, and location in the district. A study will be made of the grain size and sorting of the phosphate, supplemented by identification of the heavy minerals and clay minerals of each fraction.

<u>The overburden sand and the leached zone</u>. by J. R. Brooks.--A mechanical analysis study of the surface sands and leached zone of the Florida phosphate field has been undertaken to determine the origin of the sand and its relationship to the leached zone. It is also hoped that a variation in sorting may be found to exist in the various Pleistocene terraces.

Previous study of grain size and sorting data of the surface sands indicates that coarser and better sorted material is found on topographic highs and that there is an apparent increase in coarseness and degree of sorting from west to east. (Davidson, TEM-362, 1952)

The results of the present study are tabulated in table 5. They are not intended to depict a trend, for thus far samples have been collected only near the edge of the economic phosphate area.

The contact between the surface sands and the leached zone was picked, when possible, with the aid of gamma-ray logs. A sharp rise in radioactivity usually marks this contract.

Table 5.--Comparison of grain size and sorting in the top sand and leached zone, Land-pebble phosphate district, Florida

	Surface sand	Leached zone
Largest median diameter	0.0110 inch	0.0100 inch
Smallest median diameter	0.0063 inch	0.0082 inch
Average grain size	0.0076 inch 2/	0.0095 inch 3/
Largest S_o 1/	1.55	1.54
Smallest S_o 1/	1.37	1.29
Average S_o 1/	1.49 2/	1.41 3/

1/ S_o (Sorting Coefficient $= \sqrt{\frac{Q_1 \text{ (first quartile)}}{Q_3 \text{ (third quartile)}}}$

2/ 15 samples

3/ 7 samples

Table 2 shows that the surface sand has a median diameter range of 0.0047 inch in contrast with a range of 0.0018 inch for leached zone in samples taken to date.

Present studies indicate that the surface sand becomes finer and more poorly sorted with depth. The increase in average diameter and sorting from west to east as reported by Davidson has not yet become apparent; however, only 6 townships have been sampled. Although the average grain size difference of the surface sand and leached zone is slight, it appears to be significant, for the samples have a wide lateral range.

Samples are taken with a hand auger and are collected at every lithologic change. Separation is made on a Ro-Tap mechanical separator using 12, 20, 40, 50, 70, 100, 140, 200, and 270 mesh U. S. Standard screens. Only the upper portion of the leached zone is sampled in most cases because of the difficulty in disaggregating and screening clayey samples.

At least one sample per township will be gathered of both leached zone and top sand in 35 townships throughout the economic phosphate area.

Structural studies, by C. H. Gray, Jr.

A study of the topographic expression and vertical reflection of subsurface geologic structures in Polk and Hillsborough Counties, Florida, was begun by H. B. Dutro of the Plant City Office of the Survey in May 1952. Several structure contour maps were prepared by Dutro but before the study could be completed he was transferred to another project. The present author has undertaken to complete the work begun by Dutro.

These structural studies were prompted by certain revisions made by Vernon (Fla. Geol. Surv. Bull. 33, 1951) in the stratigraphy of the Ocala limestone of upper Eocene age. In the past all rocks of Jackson age (upper Eocene) in Florida have been assigned to the Ocala limestone. However, Vernon assigns the basal Ocala to the Moodys Branch formation, previously described in Mississippi and Alabama. Vernon further divides the Moodys Branch formation of Florida into upper and lower members, the Williston and the Inglis, respectively. According to Vernon the Williston grades upward into the Ocala while the contact between the Williston member and the underlying Inglis member is marked by a sharp lithologic change and by faunal differences. Both the Ocala-Williston and the Williston-Inglis contacts appear to be conformable.

The reference datum previously used for the study of Tertiary structures in Florida has been the top of the Ocala limestone. However, this has presented many pitfalls since the top of the Ocala represents an eroded surface. Vernon presents a structural contour map drawn on the top of the Inglis member of the Moodys Branch formation, using information secured from deep well drilling. Since the top of the Inglis member is sharply defined, but at the same time is conformable with the overlying Williston member, the top of the Inglis is presumably a valid datum against which to study the structure of the overlying rocks.

Using this Eocene limestone as a reference datum, a study is being made to determine in what manner and degree the folding of the Eocene limestones has affected the attitude of the younger formations. The possible effect on the Bone Valley formation of the land-pebble phosphate field is of particular interest.

A structural contour map prepared by Vernon shows that the Eocene limestones which underlie Polk County form a homocline which dips southwest at about 12 feet per mile. Superimposed upon the homocline are a number of secondary anticlines and synclines. Dutro felt that each of these folds might be reflected in the formations above and by a topographic feature on the present land surface.

The number of secondary anticlines and synclines superimposed on the Eocene limestone does correspond to the number of such principal features on the surface today. In a general way these folds appear to correspond roughly with the surface features. However, upon a closer inspection it is seen that they are displaced some 2 to 5 miles to the east. Whether or not this displacement is caused by the tilt of the axial planes and is thus more apparent than real, has not as yet been determined.

The Florida Geological Survey has been most helpful in these investigations and has furnished copies of all available well logs in this area.

From this data structure contour maps are being prepared and sections will be drawn. Unfortunately the deep well information is not properly spaced to permit accurate contouring. In addition the topographic control in some cases is not adequate. Since these structural and topographic features are of such small magnitude these inadequacies make it extremely difficult to arrive at significant conclusions.

In the future it is anticipated that maps and sections will be prepared from the available data. While it is recognized that the data are far from ideal it is felt that a summary of information will be of value, especially since no better information is likely to become available.

Heavy mineral and insoluble residue studies of the stratigraphic units of the land-pebble phosphate district, by W. J. Carr, D. C. Alverson, and M. H. Bergendahl

The scarcity of diagnostic fossils and the lithologic similarity in formations of the land-pebble district, and in the economic phosphate deposits particularly, have made difficult the problem of working out the stratigraphy and geologic history of the area. The writers have undertaken a study of the heavy minerals and insoluble residues of the surface sands, phosphate deposits, and associated formations in the hope that this work will supply a new line of evidence which will contribute to the solution of these problems.

Immediate objectives of this work are: (1) to determine whether significant differences exist in heavy mineral species and proportions in the overburden sands, leached zone, matrix, bed clay, and exposed Hawthorn limestone, and whether such differences, if any, are persistent laterally;

(2) to examine the heavy minerals and insoluble residues of the underlying Hawthorn, Tampa, Suwannee, and Ocala limestones in samples collected from two deep wells in Polk County, from company prospecting, and from outcrops in order to determine whether heavy minerals and insoluble residues can be used for identification of these formations.

Ultimately the heavy mineral studies will add considerably to the information being accumulated on the stratigraphy and origin of the formations of the phosphate deposits of Florida. A marker zone or zones which have a distinctive assemblage of heavy minerals would be of great value in correlation, and consequently, in determination of the origin of the phosphate-bearing formations. If, for example, it could be shown that a widespread uniformity exists in vertical distribution of heavy minerals in the unconsolidated deposits, and that the underlying Hawthorn limestone has a variety of heavy mineral assemblages, or if a distinctive marker zone of heavies is present in the Bone Valley material throughout the whole district, or large parts of it, then the evidence would point to the origin of the phosphate deposits by a theory of reworking and deposition. In other words, an angular unconformity would be strongly suggested between the Bone Valley and Hawthorn formations, as the latter has enough regional dip to expose at least 3 major lithologic units in the land-pebble district (Cathcart and Davidson, TEI-212, 1952). On the other hand, if no areal or stratigraphic continuity in heavy mineral distribution can be found, neither the depositional nor residual theory can be supported by heavy mineral evidence.

Other geologists of the Florida phosphate project will, from time to time, study the heavy minerals in limited areas, or in connection with special problems. All these data will eventually be gathered and correlated with regional studies.

Three projects are being worked on at present:

(1) Carr is taking vertical channel samples of the mine faces, each sample representative of a lithologic unit generally recognizable over a large area. These samples are panned to concentrate the heavy minerals.

(2) Bergendahl is studying the heavy minerals of three detailed sections from drill holes on the Royster tract, Polk County, Florida. The samples represent limited stratigraphic units, and are screened with U. S. Standard screens, and separated with bromoform.

(3) Alverson is studying insoluble residues from the Hawthorn, Tampa, Suwannee, and Ocala limestones.

Not enough work has been done to date to warrant presentation of any conclusive results in this report. However, examination by Carr of samples from one pit face has provided several interesting facts: phosphate appears to be more abundant in the overburden sands than has been supposed previously. In the heavy fraction of the overburden sand at one mine, about 25 percent of the grains were found to be phosphate. Garnet is virtually absent in the surface sands, but appears to increase in abundance downward in the section. Opaque minerals (probably including some black phosphate) increase steadily downward in the section from 1 or 2 percent in the heavy fraction of the surface sands to about 60 percent in the heavy fraction of the bed clay. Although these results are limited to work on one mine section and cannot show any trends, it is clear that there are significant differences in the vertical distribution of the heavy minerals.

The following minerals have been identified thus far from study of samples by Bergendahl: zircon, rutile, sillimanite, kyanite, tourmaline, staurolite, epidote, topaz, sphene, biotite, leucoxene, ilmenite, corundum, garnet, brookite, andalusite, and anatase. Collectively this assemblage of heavy minerals is broad enough to include parental rocks of the following types: ultrabasics, pegmatites, acid igneous rocks, and dynamic metamorphic rocks. It is apparent that the source of the sediments embraced a large area in which nearly all types of parent rocks were present. It is possible, however, that some of the parent rocks may have been older sediments. Grains of phosphate have been identified in the heavy mineral fraction of the Pleistocene sands and also in the clayey sand beneath the surficial sand.

Insoluble residue studies have been made of samples of Hawthorn limestone from the Pauway, Achan, Peace Valley, and Saddle Creek mines in the land-pebble phosphate field. Analyses of five parts of the Pauway sample show an average of 48.7 percent insoluble material, by weight, with an average deviation of 6.3 percent. Two parts of the Saddle Creek sample show an average of 11.4 percent insoluble material, with an average deviation of 0.8 percent. No conclusions can be drawn from these insufficient data.

If the present line of investigation by Carr suggests that further work is advisable, then more detailed sampling will be done and precise methods of screening, weighing, and separation will be employed in order to eliminate the chances of error inherent in the qualitative method of study now used. If future heavy mineral investigations are to be conducted on a large scale, use of the Trace Elements Washington Laboratory equipment including the Frantz magnetic separator and the superpanner would be indispensable in handling numerous samples.

In addition to the work on the unconsolidated formations of the district, the churn drill cuttings from 2 deep water wells being drilled for Davidson Chemical Corp. in Polk County will be examined for heavy minerals. The wells have provided an unusual opportunity to obtain samples through the entire Hawthorn limestone and underlying formations as well. The lithology of the rocks penetrated by the first well down through the Ocala limestone has been described and fossils have been selected from the samples for age determinations by paleontologists. Insoluble residues being obtained from the limestone samples by D. C. Alverson of the Survey staff will be examined for heavy minerals by Carr. When the work is completed the results in the two wells will be compared. If there is any reasonable correspondence between the results, then the data may be used with some assurance in future work. Particular emphasis, of course, will be placed upon the Hawthorn formation in order to determine how the heavy minerals compare with those in the overlying unconsolidated material. Studies of heavy minerals should also aid in working out the stratigraphy of the Hawthorn formation.

Bergendahl will complete work on the three detailed sections from the Royster property, and Alverson will collect further samples for insoluble residue studies from the Hawthorn and underlying formations.

As work on subsurface samples progresses, phosphate from the Tampa and Suwannee limestones, and particularly the Hawthorn formation will be analyzed chemically to determine more precisely how it differs from the

Bone Valley formation phosphate in content of P_2O_5, U, CaO, and other significant elements. Heretofore very little chemical or mineralogic work has been done on the phosphate of the underlying limestone formations, chiefly because of the difficulty of obtaining samples and removing the phosphate from the rock. However, the churn drill cuttings are easily handpicked for phosphate.

Weathering in the land-pebble phosphate district of Florida, by L. V. Blade

The object of this study is to determine the nature and the importance of weathering on the land-pebble phosphate deposits of Florida.

The results to date have been a consideration and formulation of the problem. A sampling program has been started that is designed to yield more mineralogical data with particular stress on the -0.074 mm fraction.

The problem of weathering and the problem of origin of the phosphate deposits in the land-pebble district of Florida are interdependent.

To date two hypotheses have been advanced to explain the origin of the deposits. The depositional hypothesis was set forth by Sellards (1915). This hypothesis postulates erosion of the Hawthorn formation at the end of Miocene time, deposition in Pliocene time of the lower unit of the Bone Valley formation in a shallow marine near-shore environment, the upper unit of the Bone Valley in a marine off-shore environment, subsequent erosion, and finally, deposition in Pleistocene time of surficial terrace sands. The residual hypothesis has been proposed by Ketner (Cathcart, et. al., TEI-265, pp. 17-19). This hypothesis attempts to account for the entire sequence of unconsolidated material overlying the Hawthorn formation as the relatively insoluble residue of the Hawthorn formation that has been concentrated in place by weathering.

Also possible is a modification of the depositional hypothesis which explains the upper part of the Bone Valley formation as the weathered remnant of material similar in character to that found in the lower Bone Valley.

Material larger than -0.074 mm in the Bone Valley formation has been fairly well identified and described but material smaller than -0.074 mm has practically been ignored. Little has been done with material in the Hawthorn formation.

Areal mineralogical studies of both formations are needed before the role of weathering can be effectively evaluated.

The samples taken for mineralogical study of the upper Bone Valley formation can also be used to study further the correlation of Al_2O_3, P_2O_5, and U which was discussed by the author in a report in preparation (TEM-503). The element calcium should be included in this study since there is a strong possibility that a significant correlation may be found between Al_2O_3, P_2O_5, CaO, and U.

<u>Origin, mode of occurrence, and distribution of phosphate and uranium</u>, by J. B. Cathcart

The end point of most of the geologic studies of the Florida phosphate project is to determine the origin of the deposits of phosphate and uranium. TEI - 280 presented the hypotheses of the origin of the land-pebble phosphate deposits.

As has been pointed out above by Ketner, the general mineralogy of the land-pebble district and the hardrock district are very similar. Too little work has been done on the South Carolina deposits to determine the mineralogy, but in holes drilled to date no "leached zone" has been found. However, there are differences between the South Carolina and Florida deposits as well as similarities. The source of much of the phosphate in the land-pebble district of Florida, and in South Carolina, appears to be the nodular phosphate of the Hawthorn formation. There is a suggestion, but as yet no direct evidence that the Hawthorn formation once covered the area of the hardrock field, and that it may be the source of the phosphate there. The phosphate of the hardrock field occurs as irregular blocks, as clay-size material, and as "plate rock" encrusting the underlying Ocala or Suwannee limestones. The latter type is apparently a limestone replacement.

Work on heavy minerals, insoluble residues, and stratigraphy has been aimed at making clear the geologic history and origin of the deposit. This work has been briefly summarized by various authors in this report.

Work in the future will develop these lines of investigation, correlate them, and arrive at a general hypothesis for the origin of the phosphate in the Hawthorn, Bone Valley, and Alachua formations, and the South Carolina field.

The mode of occurrence and distribution of phosphate and uranium have been summarized in TEM-243 and TEM-436.

Future work will be directed toward: (1) bringing the maps of uranium distribution up to date as new information is available; (2) defining relationships of uranium to other elements, particle size, stratigraphy, and "basement topography"; (3) defining the relationships of the leached zone to stratigraphy and to topography, both present and past; and (4) determining the origin of the phosphate and uranium in the leached zone and the matrix.

Resource studies

Geology and reserves of phosphate and uranium on the Royster tract, Polk County, Florida, by M. H. Bergendahl

Logging and sampling of drilling on the Royster tract was completed in June, 1952. Drilling was conducted on an eight hole per forty acre grid, and a total of 341 holes were drilled. Estimations of tonnage and grade of uranium and phosphate in the leached zone and matrix have been suspended, pending the receipt of analyses from the Washington laboratory.

An isometric fence diagram has been prepared on a scale to show all of the major lithologic units encountered in the drilling. This detailed information reveals an extreme irregularity in the thickness of the various units from point to point as well as a substantial thickness of economic phosphate throughout the tract.

The Hawthorn formation of Miocene age is a light grey to buff colored silty fossiliferous limestone, containing phosphate nodules. At the surface of the Hawthorn formation is a calcareous phosphatic clay of variable thickness that may be either a residuum of weathering or else reworked material deposited by the invading Bone Valley sea. Drilling was usually halted when this calcareous material was encountered; this point was considered the top of the Hawthorn formation.

A subsurface contour map of the top of the Hawthorn formation reveals the following features and relationships:

1. A trough trending north-south which may have been part of a former river channel.

2. Superimposed on the topographic highs and the trough are numerous sink holes, possibly a result of ground water action.

3. No relationship exists between the subsurface topography on the Hawthorn formation and present topography, except in the eastern part of the tract, where a Hawthorn high closely parallels a prominent topographic ridge. Otherwise, present topography is influenced by the Peace River drainage pattern.

4. Areas where the pebble to concentrate ratio in the Bone Valley formation is greater than one bear no relationship whatsoever to the topography of the underlying Hawthorn formation. This is in contrast with conclusions drawn by Davidson, (TEM-337) wherein a direct relationship between topography of the Hawthorn formation and phosphate particle size was found in the northern part of the land-pebble district.

The Bone Valley formation is composed of two units--a lower bedded marine phosphorite and an upper leached zone. On the Royster tract the lower part of the Bone Valley formation is from 6 to more than 54 feet thick. The greatest thicknesses are where the surface of the Hawthorn formation is the lowest.

Throughout most of the tract the thickness of economic phosphate is twenty feet or greater. Tons-per-acre data have not as yet been assembled; however, the total will be substantially high, compared with tracts of equal size in other parts of the land-pebble field. Scattered areas where the pebble to concentrate ratio of phosphate exceed one, aggregate less than 1/10 of the entire tract.

The upper part of the Bone Valley formation is said to composed of two major lithologic units: a clayey quartz sand and a clayey sand containing leached phosphate pebbles and indurated vesicular sandy nodules. On the Royster tract, these units are not continuous, nor do they everywhere occupy the same stratigraphic position. Usually the clayey sand overlies the vesicular material, but in some holes, lenses of clayey sand were encountered directly above the matrix as well as within the vesicular material. The vesicularity in the indurated nodules and the presence of wavellite as both a cementing material and also as occasional spherulitic aggregates, indicate that phosphate nodules have been removed from this material and that the phosphate was redeposited as an aluminum phosphate. In the clayey sand, however, no megascopic criteria for leaching or replacement can be observed from auger cores. The composition of the clay-size material is not known and cannot be determined with the equipment available. Chemical analyses of clay-size material in the so-called upper Bone Valley formation are a prerequisite to any detailed stratigraphic studies of this material.

Another possibly significant feature of the so-called upper Bone Valley formation encountered on the Royster tract is the presence of lenses of white quartz sand within the clayey sand. In some areas these sand lenses are directly above the matrix. Such lenses of sand are from 1 to 30 feet thick and occupy areas of up to 100 acres.

Utilizing drill log interpretations and hand lens observation of auger cores, the writer cannot offer any concrete evidence pertaining to the stratigraphic disposition of the clayey sand and sand lenses beneath the surficial sand. The following facts, however, compel the writer to question the assignment of all clayey sand on the Royster tract to the upper Bone Valley formation:

1. The complete absence of visible evidence of leaching.
2. The lack of relationships among distribution and thickness of clayey sand, visibly leached material, and the underlying phosphate deposits. Neither the clayey sand nor the visibly leached material is a continuous stratigraphic unit throughout the tract. Both are present as lens-like deposits of varying thicknesses which may merge into one another within several hundred yards. Where both units are present, the clayey sand generally is found above the vesicular material, but occasionally these relationships are reversed.
3. Thick lenses of pure quartz sand within and beneath clayey sand.
4. The variation in thickness of upper Bone Valley material which has been visibly leached. It seems improbable that environmental conditions necessary for leaching should vary over a small area to produce the areal and stratigraphic extremes in visibly leached material encountered at the present time. The lower Bone Valley formation is a relatively homogeneous lithologic unit and should be affected uniformly by leaching.
5. No relationships between thickness of visible leached zone and present topography and thickness of leached zone and topography of the top of the Hawthorn formation are apparent. In other words, an unconformity could be present at the top of the vesicular leached material, although no evidence has been found to substantiate such an assumption.

The possibility remains, however, that the clayey sand and sand lenses represent degrees of leaching; consequently, this material could be included within the upper Bone Valley formation. Chemical analyses are necessary before such an assumption can be accepted as factual.

Loose surficial quartz sands have been assigned by Roundy (USGS Bull. 906-F, 1941), MacNeil, (USGS Prof. Paper 221-F, 1950) and others to the Pleistocene. On the Royster tract those sands range in thickness from one foot to more than sixty feet.

Phosphate studies in the eastern Gulf of Mexico
by H. R. Gould

Investigations of bottom sediments in the eastern Gulf of Mexico were undertaken by the Survey in July 1951 to determine the areal distribution, quality, source, and mode of formation of phosphatic sediments in this region. Earlier observations, supplemented with notations of bottom type recorded on nautical charts of the U. S. Coast and Geodetic Survey, suggested that phosphatic sediments were confined chiefly to the inner 25 miles of the continental shelf between Tarpon Springs and Fort Myers, Fla. Profuse dinoflagellate blooms (red tide), which are thought to be spawned by phosphate-rich waters, develop periodically in this same general area. This correspondence in distribution suggested that the red tide and the phosphate in the bottom sediments might have a common origin, and that the phosphate might be in the process of formation today. On the other hand, it seemed possible that the phosphate on the sea floor might be a submarine extension (or reworked submarine extension) of Tertiary deposits on the Florida peninsula, or that the phosphate might have been contributed by rivers draining the peninsular deposits.

As a result of these preliminary observations, field studies have been confined chiefly to the continental shelf between Tarpon Springs and Fort Myers, Fla. and to the rivers entering the Gulf in this region. Reconnaissance studies of more limited scale have been made as far west as Mobile, Ala. These studies, together with oceanographic and bottom sediment data contributed by the U. S. Fish and Wildlife Service from other parts of the Gulf, provide valuable information for comparison with that obtained from the Florida offshore area. Altogether, 2,900 sediment samples, 26 dredge hauls, 9 cores, and 137 water samples have been collected. Of these, 2,560 bottom samples, 1 core, 26 dredge hauls, and 112 water samples were obtained from the continental shelf off the west coast of Florida and from rivers entering the Gulf in this area. The remainder of the samples were obtained from other regions of the Gulf.

Studies during the first half of this fiscal year have been confined chiefly to laboratory analyses of bottom sediment and sea water samples collected during fiscal year 1952. Approximately 130 sea water samples have been analysed for their total salinity, phosphate, and uranium contents. Phosphate and uranium analyses of about 300 sediment samples are being made to complete the picture of phosphate and uranium distribution and to supplement information in areas of critical interest. Micropaleontological analyses of approximately 370 bottom samples and 9 cores are being made to determine, in part, the age of the phosphatic sediments and the age of foraminifera that have been replaced by phosphate. Studies of the mass physical properties of all samples have been completed. Mineralogical, petrographic, and partial chemical analyses of several selected samples are in progress.

Results

Preliminary results show that the continental shelf sediments between Tarpon Springs and Fort Myers consist of 6 types which occur in regular bands or zones paralleling the coast. These zones, arranges according to distance from shore and depth range are listed in table 6.

Table 6.--Distribution of sediments in eastern Gulf of Mexico

Zone no.	Sediment type	Distance from shore (nautical miles)	Depth range (fathoms)
1	Quartz-shell sand (50%-100% quartz)	0-20	0-10
2	Quartz-shell sand (0%-50% quartz)	20-40	10-15
3	Shell sand and gravel	40-65	15-30
4	Algal sand and gravel	65-80	30-40
5	Oolitic sand (calcareous)	80-90	40-50
6	Foraminiferal sand	90-120	50-100

Available analyses and binocular examination of all samples show that higher than normal phosphate occurs only in zone 1. Most of the samples in this zone contain only a trace of phosphorite, generally in the form of well-rounded ovules or as replacement of foraminifera and other calcareous debris. From visual comparison with chemically analysed samples it is estimated that most of the samples in this area contain less than 0.50 percent P_2O_5 and hence less than 0.001 percent uranium. However, in a few scattered areas within zone 1 phosphorite ovules and phosphatized foraminifera make up an appreciable part of the bottom sediments. These areas of phosphate concentration occur in near-shore waters between Englewood and Venice, Fla. and between St. Petersburg and Tarpon Springs, Fla. An area of lesser concentration is located in the southeastern part of Tampa Bay near the mouths of the Little Manatee and Alafia Rivers.

In the Venice-Englewood area there are 4 zones of phosphate concentration which range in area from less than 1 square mile to about 4 square miles. The inner margins of 3 of these zones are less than a mile from shore, and one is continuous to the shore where sediments similarly high in phosphate are exposed on the beach. Available analyses of samples from these areas permit no close estimate of their average P_2O_5 and uranium contents. However, analyses of a few samples from these areas have P_2O_5 and uranium contents of as much as 13.4 percent and 0.0040 percent, respectively.

In the St. Petersburg-Tarpon Springs region, at least 7 areas of phosphate concentration have been recognized. They range from one to two square miles in area and occur at distances of from 3 to 15 miles from shore. Although no chemical analyses are yet available from these areas, visual comparison with analysed samples suggests that they are somewhat lower in P_2O_5 and uranium than samples from the inshore areas between Venice and Englewood.

The Tampa Bay phosphate zone covers an area of about 15 square miles and ranges in P_2O_5 content from 0.50 to 6.24 percent; the uranium content ranges from 0.0001 to 0.0004 percent.

No phosphorite has been detected in any of the samples seaward of zone 1 (table 6). Likewise, chemically analysed samples from this region have an average P_2O_5 content of less than 0.15 percent and a uranium content of about 0.0001 percent.

Conclusions

The sediments of the inshore zone (zone 1), as shown by their high quartz content, are chiefly detrital, whereas sediments of the other zones (zones 2-6) are largely organic. Sediments of the inshore zone are generally similar to those of adjacent beaches and to those carried by rivers entering the Gulf in this region. It seems clear, therefore, that the beaches and rivers are the sources of much of the sediment in zone 1. The general dissemination of phosphorite throughout zone 1 and its absence in the outer zones suggest that it is also being supplied by rivers draining the peninsular phosphate deposits and by adjacent phosphatic beaches.

The small areas of phosphate concentration within the inshore zone do not appear, however, to be entirely of detrital origin. On the other hand, it seems probable that submarine outcrops of older formations may be, at least in part, the sources of unconsolidated concentrations of phosphatic sediments in this zone. Dredged rock from the St. Petersburg-Tarpon Springs area shows that one of the areas of phosphate concentration is underlain by limestone containing abundant phosphorite ovules. Similarly, phosphatic coquina dredged from one of the areas of phosphate concentration in the Venice-England region suggests that it is, in part, the source of the overlying phosphatic sediments.

The replacement of foraminifera tests by phosphate in some of the samples deserves further study. Attempts are currently being made to determine their age and the mode of phosphate replacement.

Future Plans

Field studies, although mostly complete, will be supplemented with the collection of about 50 water samples and 50 sediment samples from the upper courses of the Peace, Myakka, Little Manatee, and Alafia Rivers. Laboratory studies currently in progress and those necessary for completion of this project will be continued. It is anticipated that most of the laboratory work will be completed by the end of this fiscal year, and that the final report on this project will then be about 50 percent complete.

SEARCH FOR URANIUM IN NATURAL WATERS
by P. F. Fix

A preliminary investigation of the occurrence of uranium in natural waters was made by the Geological Survey on behalf of the Division of Research of the Atomic Energy Commission during the second half of 1951.

The objectives of this investigation are: (1) to search for non-saline waters containing enough uranium to be recoverable economically; (2) to determine the geologic origin, relationships, and behavior of uranium in natural waters; and (3) to develop geochemical prospecting techniques for uranium based upon the amount and relationships of uranium in natural waters.

This report summarizes briefly the work accomplished to the end of the 1952 field season; a more detailed report will be prepared when all laboratory analyses have been received. TEM-281 (Aberdeen, et al., 1952) summarizes results of the work through the spring of 1952 in some detail.

A total of 135 samples of uranium-bearing natural waters, 120 of which were collected for uranium determination, and 15 of which were for partial chemical analysis as an aid in field work, has been collected to date from 17 different states. Of the 120 samples collected for uranium determination, 44 are from uranium-mining districts, 25 are from thermal springs (5 in uranium-mining areas), 19 from acid tuff and arkose areas, 12 from phosphatic areas, 10 from black shales and coal-bearing strata, 1 from drainage from a uranium-processing mill, and 9 from miscellaneous sources.

Of all uranium determinations received to date, 48 percent contained more than 1 ppb, the present apparent threshold of significance, and 18 percent contained 10 or more ppb, the present apparent threshold of major significance.

During the field season of 1952, a rough but quantitative geochemical prospecting technique was developed and used during field work in western Montana. It is believed that this technique can be refined in another year of field work to a point of general usefulness.

Two possible sources of non-saline waters from which uranium might be recoverable economically have been found.

Appreciable quantities of uranium may be present in streams that drain areas occupied by uranium-ore processing plants. This is indicated by samples collected from the San Miguel River, Montrose County, Colorado, in August 1952 near the processing plant operated for the Atomic Energy Commission by the Vanadium Corp. of America about a dozen miles above Uravan. A sample from the river 0.9 mile above the plant contained 1.0 ppb, and a sample collected 1.2 miles below the plant contained 55 ppb. The river, which at the time was in the falling stage of a flash flood from several days of heavy rains in its drainage basin, has an average discharge volume of about 400 cfs, a recorded maximum of 7,100 cfs, and a recorded minimum of 12 cfs. Additional samples will be taken periodically to establish the range of uranium content. The mill at Uravan and other uranium-processing mills will be investigated also.

Naturita Creek, tributary to the San Miguel River near the town of Naturita, may possibly be a source of uranium also. A sample collected below the forks of the creek about 4 miles northeast of Naturita in August 1952 contained 9.3 ppb. The average discharge is believed to be of the order of about 30 or 40 cfs. The recorded maximum is 943 cfs, but the creek may be dry for weeks at a time in the autumn. Additional samples will be collected periodically to establish the range of uranium content, and possible derivation of uranium from ore dust dropped from trucks on the watershed will be investigated.

The hope aroused by a laboratory report showing 77 ppb of uranium in a September 1951 sample from Cimarron Creek in Montrose County, Colo., apparently was nullified by resamples taken in February and late August 1952 showing, respectively, only 2.6 and 2.9 ppb of uranium in water from the original sampling site. Supplementary new samples in August 1952 from the two branches of the creek above the forks showed only 2.6 and 3.0 ppb. The report of 77 ppb from 1951 may have been a laboratory error; investigation is continuing in an attempt to determine the source of the uranium, and whether the creek may at times carry an unusually large amount of uranium such as reported for September 1951. Additional sources in the vicinity were sampled in 1952; the largest amount of uranium found in any was 2.3 ppb.

Conclusions

Some tentative conclusions on geologic relationships may be stated briefly. Natural waters of very acid or very alkaline nature seem more conducive to occurrence of significant amounts of uranium than do waters that are nearly neutral; enough results are not available to make this generalization conclusive.

A high content of sulfate seems very favorable if other factors present are suitable. Significant amounts of uranium have been found in sulfate waters containing one or more of the following in considerable amount: calcium, magnesium, iron, and sodium.

A total hardness, as $CaCO_3$, of 300 or more, other factors being suitable, seems highly favorable. Most of the samples showing greatest amounts of uranium to date have hardness greater than 300, and the greatest uranium content found was in a water showing 992. Hardness greater than 300 does not necessarily mean uranium is present, of course.

A high content of sodium seems favorable, but high uranium content has been found in presence of very little sodium in some samples. Silica content of water seems related to uranium occurrence; 10 to 30 ppm of silica seems favorable. Fluoride also seems related to uranium content.

The ratio between calcium, magnesium, and sodium seems significant.

Plans

The tentative general plan of procedure in the investigation through June 1953 is to make reconnaissance investigations of areas believed to be favorable, and to follow with as many stages of intensifying detailed work as results seem to justify.

The following is anticipated in the second half of the year: (1) continued investigations in the uranium-mining areas of Montana, Colorado, and Utah, to evolve geochemical techniques; (2) continued investigation of waters draining acid tuffs and black shales, and waters from other rocks that may contain concentrations of uranium suitable for recovery; and (3) sample waters in the vicinity of uranium mills on the Colorado Plateau. A progress report is in preparation.

SEARCH FOR AND GEOLOGY OF THORIUM AND MONAZITE DEPOSITS

Reconnaissance and resource studies
by J. C. Olson

The objectives of this investigation are to determine the distribution, mineralogy, geologic relations, and economic potentialities of thorium deposits, and by geologic study of selected thorium districts, to find geologic guides to thorium that might be applicable to areas in which thorium is not now known.

Geologic investigations were carried on during the past half-year in the Mountain Pass district, San Bernardino County, California; the Lemhi Pass district, Idaho-Montana; a recently discovered area containing hard-rock monazite deposits near Shoup, Lemhi County, Idaho; and the Powderhorn district, Gunnison County, Colorado. One-day examinations were made of the St. Peters Dome thorium-bearing pegmatites, Colorado, and the monazite deposits of the Deadwood formation, Big Horn Mountains, Wyoming.

In the Mountain Pass district, thorium and rare earth deposits have been found in a belt 6 miles long. The thorium-bearing veins studied are (1) the large Sulphide Queen carbonate body, about 2,400 feet long, which contains sparse monazite, and (2) carbonate veins and mineralized shear zones in which thorite is the chief thorium mineral. The mineralized shear zones on the Ray-Welch-Willmore and Windy groups of claims are 3,000 and 2,000 feet long, respectively, and contain individual veins as much as 300 feet long and 5 feet thick. The grade of the Mountain Pass thorium deposits ranges generally between 0.02 and 0.5 percent ThO_2, and local concentrations are as much as 5.5 percent ThO_2. The following thorium deposits in the Mountain Pass district have been studied in detail and locations shown on the geologic map of the Mountain Pass district: Birthday-Sulphide Queen area deposits; Candy and Cake No. 3 claim; Alice Claim; Unnamed prospect No. 1; Bullsnake claim; Reynolds Robbing group of claims A, B, C, and D; Simon-Ray claim; Ray-Welch-Willmore claims; Goulder Goulch claim; Unnamed No. 2; Doty claim; Windy group of claims; and Unnamed prospects Nos. 3 and 4. Thorium reserves have been inferred for these deposits, individually and collectively, and are presented in TEI-251, now being processed, on "Thorium resources of the Mountain Pass district, San Bernardino County, California," by D. R. Shaw.

In the Powderhorn (Cebolla, White Earth) district, reconnaissance for thorium was carried on during about three weeks. In addition to the localities listed by Burbank and Pierson (TEM-310), radioactive deposits have also been found in sec. 32, T. 48 N., R. 3 W.; secs. 3, 10, and 15, T. 47 N., R. 3 W.; and secs. 11, 15 and 16, T. 47 N., R. 2 W. In the immediate vicinity of Iron Hill, abnormal radioactivity was also found in carbonate veins in secs. 3, 12, 13, 14, T. 46 N., R. 2 W.; in secs. 1, 2, 11, 12, T. 46 N., R. 1½ W.; and in sec. 7, T. 46 N., R. 1 W. All the analyses made so far of material from this district indicate that the radioactivity is due to thorium. The equivalent uranium in 7 representative samples of the thorium-bearing veins ranges from 0.004 to 0.13, indicating roughly 0.02 to 0.65 percent ThO_2, although selected samples contain as much as 2.29 percent ThO_2.

Various parts of the main carbonate mass that makes up Iron Hill, in the Powderhorn district, were checked with the Geiger counter, but the maximum reading was only about twice background. These rocks were also examined with the hand spectroscope for rare earths, which are believed to occur largely in apatite. Rare earth-bearing apatite is widespread in the carbonate rock in small percentages. Spectrographic analyses of 3 representative samples of apatite-bearing carbonate rock show generally 0.X La, 0.X Ce, and 0.X Nd. Five chemical analyses of the carbonate rock failed to show more than 0.1 percent combined rare earth oxides, suggesting that total rare earths probably are not sufficiently abundant to constitute a commercial deposit for rare earths. The Powderhorn district is considered a promising one for thorium, and like Mountain Pass it provides an example of the concentration of thorium and other rare elements in alkalic rock provinces.

The hard-rock thorite deposits, as typified by Mountain Pass, Powderhorn, and Lemhi Pass, appear to contain significant quantities of thorium, but also would probably present problems of beneficiation in event of their exploitation. Thorium, like several other uncommon elements, appears to be concentrated in some alkalic igneous rock provinces, and such areas are relatively promising for prospecting. Minerals such as barite, fluorite, and hematite appear to be associates of thorite in many of the deposits.

The search and appraisal of thorium deposits is expected to continue in next fiscal year with both field and literature studies of known deposits. The continuing review of geologic relations of thorium deposits should result in the formulation of additional geologic guides to thorium, to be tested in reconnaissance examinations of other areas considered favorable for the occurrence of thorium. The work during the next six months will consist largely of preparation of reports and laboratory work relating to the Lemhi Pass, Shoup, and Powderhorn districts, and the review of data on thorium occurrences in the files and in geologic literature.

Southeastern Coastal Plain reconnaissance
by Lincoln Dryden

The objectives of the project are: (1) a long-range search for the methods by which heavy mineral concentrations have been formed in the coastal plain, so that future exploration may be put on a scientific basis; and (2) a more immediate search for large-scale concentrations of potential economic importance. In practice, the two objectives are constantly being considered in relation to one another, as two aspects of the same problem.

At present, attention is being concentrated on Pleistocene shoreline features - such as beaches, bars, spits, and dunes - in the expectation that concentrations found in association with such features may be of large scale--that is, of the order of magnitude of a million tons of heavy minerals. A further expectation, borne out by one producing deposit and by company information on others, is that such large scale concentrations may contain monazite in by-product quantities.

Two companies--Dupont and National Lead--are now large producers of heavy minerals from the coastal plain. In addition, each has spent several years in a search for new deposits, and the information that has been made available from their work naturally has had an influence on the course of this project. Both companies have conducted extensive and intensive sampling, and have outlined several areas for possible development. They have carried out reconnaissance throughout the most promising parts of the coastal plain and have at the same time delimited areas of much less promise. In view of this work already accomplished, the present project is necessarily directed toward: areas, such as Virginia, Maryland, and Delaware, where little or no work has been done before; to less favorable geologic situations, such as the higher terraces and shorelines; or to smaller areas or to details which the companies have not examined. It should not be expected, then, that this project would discover as many, or as large heavy-mineral concentrations as have these two companies working over the last several years.

Methods.--The first approach is essentially a topographic one. The problem is one of finding an ancient beach or other feature which has been so well washed and sorted that clean sand has been accumulated in large quantity. Soils maps aid in locating sands. Whether such sands, once found, will contain significant amounts of heavy minerals is, up to the present, to be settled only by sampling. Sampling is carried out by hand-augering, and the sand so obtained is tested in a Vanning-type pan. Such panning serves to give a rough idea of the percentage of heavy minerals present. For sands of more than nominal content, a field method employing bromoform separation is used to get a more precise figure. For any concentration of interest, mineral counts are made under the petrographic microscope. Such counts are also made to show up regional differences in heavy minerals.

Results

Eastern shore of Maryland and Virginia.--The first two weeks of field work were carried out in this area, both in a search for mineral concentrations and in a test of field methods. About half the time was spent along the prominent scarp that appears typically about five miles southeast of Snow Hill (Snow Hill, Md. quadrangle). In most of the Maryland part of the scarp, the lithology proved to be a mixture of largely unsorted silt, sand, and pebbles, and heavy mineral percentages were extremely low. Toward the south, more sand was found along and near the scarp. Still farther south (Mappsville, Va., 7½' quadrangle) this sand increases sharply in mineral content. For a length of about two miles, a width of a half to one mile, and a depth (attainable by hand auger) of six to ten feet, there is a heavy mineral content of from 2 to 6 percent. This concentration has not been outlined in further detail, pending wider reconnaissance elsewhere in the coastal plain. Other, smaller concentrations found in the same general area lead to the conviction that the Eastern Shore, hitherto unexplored, is worth further and more extensive examination.

Kilmarnock area, Lancaster and Northumberland Counties, Virginia.-- An area near the town of Kilmarnock, between the Potomac and Rappahannock Rivers was examined for a few days (Kilmarnock, Va. quadrangle). Just east of the town, the prominent scarp was found (as in the case above) to be made largely of unsorted materials. But farther south, around White Stone and toward the Rappahannock River, the proportion of fairly well-washed sand increases. Again, the heavy mineral content increases sharply. For a length of about three miles, a width of a mile or so, and an attainable depth of from four to fourteen feet, the sand has a mineral content which will probably average between three and four percent. Preliminary microscopic examination of two samples shows very high proportions of economically valuable ilmenite. Away from the scarp, the main body of the Pleistocene terraces is made up of largely unsorted material, with low mineral content.

It is concluded, from the one occurrence near Kilmarnock, that the western shore of Virginia, adjacent to Chesapeake Bay, is an area of potential economic interest.

Other areas in Virginia.--Two areas in Virginia, examined in rapid reconnaissance, have so far proved negative. One lies along and to the east of the Surry scarp (roughly the course of the 100 foot contour through the Surry, Va. quadrangle and to the south). It had been expected from published reports that the scarp itself might be in considerable part made of sand, and that former off-shore bars might lie to the east of it. No significantly large bodies of sand were found in the brief period of work.

A second area is that lying south and east of Norfolk. Special attention was paid to the trends running south-southwest from Virginia Beach, as being possibly old shorelines. These proved to be only in part sand, and to have comparatively low mineral content. In other parts of the area, large bodies of clean sand showed almost no content of heavy minerals.

Conclusions.--At present, little is known as to the method of formation of heavy-mineral concentrations, so that any conclusions are both tentative and tenuous. One, is that greater scarp height and steepness are an indication of poorly sorted material, so that sand is more likely to be found where the scarp flattens. Another, is that there is greater probability of sand as one goes south along a scarp, presumably as a result of southward long-shore drift. Another, is that heavy minerals are likely to accumulate where there is a change in direction in the scarp or other feature.

Plans for future work.--In general, the plan is to continue the same sort of rapid reconnaissance that has been done in Maryland and Virginia, progressing southward as frozen soil and other conditions make work in the north unprofitable. No attempt will be made to outline any mineral concentration to the full extent, since for one thing it will ordinarily be impossible to bottom such deposits with hand augers. But if any concentration gives promise of contributing to the theory of formation, such deposits will be examined as closely as time and equipment permits.

District Studies

Southeastern monazite exploration
by W. C. Overstreet

Southeastern Monazite Exploration is a reconnaissance study of fluvial placers in the western Piedmont of Virginia, North Carolina, South Carolina, and Georgia. The object of this study is to describe local monazite deposits, to determine geologic controls of placer deposition, and to evaluate placer potentialities of the western monazite belt outlined by John B. Mertie, Jr.

Work toward completion of the project is divisible into field studies, cooperative physical exploration with the U. S. Bureau of Mines, and report writing. In the six-month period between June 1 and November 30, 1952, field studies were pressed, the Bureau began exploration of sites in North and South Carolina, and preparation of reports began.

Field studies include reconnaissance of the western monazite belt and detailed study of one stream. From June through November members of the field party engaged in reconnaissance of the western belt, studied 389 streams draining 3089 square miles in 27 counties in four states. (Table 7.) The area covered in this period is shown on index maps submitted with monthly reports during that time. This area comprises five districts: (1) the district between the Catawba River in North Carolina and the Savannah river between South Carolina and Georgia, (2) the Mr. Airy district in North Carolina and Virginia, (3) the Athens district in Georgia, (4) the Zetella district in Georgia, and (5) the LaGrange district in Georgia.

With the exception of about 100 square miles in Lincoln County, N. C. (in the Catawba River - Savannah River district) field work in all five districts was completed by the end of November.

Table 7.--States and counties studied June through November 1952, Southeastern Monazite Exploration

State	Counties studied 1/	State	Counties studied 1/
Virginia	Patrick	South Carolina	Cherokee
			Spartanburg
North Carolina	Scurry		Greenville
	Stokes		Greenwood
	Catawba		Abbeville
	Burke		Laurens
	McDowell		Anderson
	Polk		
	Rutherford	Georgia	Clarke
	Cleveland		Oglethorpe
	Lincoln		Oconee
			Barrow
			Jackson
			Spalding
			Pike
			Troup
			Harris
			Meriwether

1/ Only those parts of each county were studied that lie within or adjacent to the western monazite belt.

Field studies of streams in the five districts required mapping margins of floodplains on 1:20,000 scale aerial photographs, collecting heavy mineral concentrates from grab samples of the different types of alluvial sediments in the drainage of each stream, measuring exposed sections of sediments, and auger drilling to determine thickness and sequence of sediments. As part of field work 2451 grab samples were taken and 298 auger drill holes, totalling 5265 feet in depth, were drilled.

A detailed examination of Knob Creek in Cleveland County, N. C., was begun in mind-June. The purpose of this study is to provide specific data on migration and concentration of monazite in a typical stream flowing on the saprolitic bedrock of the western Piedmont. These data will be useful in assessing geologic processes operative elsewhere in the monazite belt. When work was temporarily halted on this study at the end of October, about 40 percent of the examination was completed.

Physical exploration of selected areas on streams in North and South Carolina was begun by the U. S. Bureau of Mines in September. Seven of the nine areas being drilled in the Catawba River—Savannah River district were proposed by the Survey in memoranda dated Aug. 18 and Oct. 22, 1952. Each site combines different assemblages of environmental factors; conditions obtaining at any site that may prove to be minable can be evaluated and similar sites could be selected elsewhere in the belt to match conditions proved by exploration to favor accumulation of heavy minerals. Maps at 1:4,800 scale of the drilled sites are in preparation.

Results of a long-term investigation do not follow immediately upon completion of field work. A period at least equal to the time spent in the field is needed to collate data, prepare maps, and evaluate samples. Until that office work is done no firm appraisal of the area can be made. Some tentative general observations on geologic controls of heavy-mineral deposition in the belt appear justified, but limitations in this report prevent more than topical listing:

(1) The amount of monazite in source rocks can be correlated to level of metamorphism and composition of the source rock.

(2) The amount of monazite in fluvial sediments can be correlated to grain size and sorting of the sediments.

(3) The distribution of monazite along the course of a drainage system can be related to the brittleness of monazite, the rate of deposition, and the age of fluvial sediments.

(4) Differences in fluvial sedimentation within the belt from west to east and from north to south can be related to topography, bedrock geology, and stream history.

(5) Within individual drainages sequences of fluvial sedimentation are consistent.

Between the end of November 1952 and June 1953 the field party will prepare maps and portions of text for joint reports on areas drilled by the U. S. Bureau of Mines in the western Piedmont of North and South Carolina, will write an interim report on progress of reconnaissance, and will be at work on a final report to be transmitted in fiscal 1955. Completion of each report of the joint series will follow field and laboratory work; and the interim report on progress of reconnaissance will be transmitted in the spring of 1953. No further reconnaissance is planned in the western monazite belt until the final report on the present investigation has been completed.

Wet Mountain project, Custer County, Colorado
by Q. D. Singewald and R. A. Christman

During fiscal years 1951-1952, the U. S. Geological Survey discovered a metallogenic province containing thorium in veins along the western slope of the Wet Mountains. Almost two dozen radioactive deposits occurring along north-northwest trending shears were found; three of the most promising areas were mapped (scale 1:1,200), and a diamond drilling program was conducted at Haputa Ranch.

In fiscal year 1953 a program of systematic areal geologic mapping was begun (scale 1:6,000) in a 60-square mile tract that includes most of the presently known thorium occurrences. The purpose of the study was to delineate the thorium province, to methodically search for new deposits, and to ascertain the geologic setting of the known deposits in order to develop geologic guides to deposits that might be worked commercially.

During June and the first half of July, the compilation of data pertaining to the physical exploration at Haputa Ranch was completed. Plane table maps with the radioactivity indicated by isorads were made of the Sewell and Anna Lee properties. All known thorium localities were revisited and their positions accurately located on the newly obtained topographic maps.

Systematic geologic mapping began in mid-July; five square miles were mapped during the 1952 field season. The progress was slow because of the difficulty in (1) establishing feasible mapping units in view of the exceedingly complex geology and in (2) working out the best mapping methods. Five principal rock types were established: microcline granite with two varieties or facies; impure granite characterized by relics, wisps, laminae, and inclusions of gneissic material; and three varieties of hornblende gneiss ranging from extensively soaked "injection gneiss" to gneiss nearly free of "injected" granitic material. These rocks were mapped, in part, as individual units, but generally two or more occurred together in various proportions as an interlayered sequence; a large number of sequences were established. In addition, seven varieties of dikes ranging in composition from basalt to aplite, a rock tentatively mapped as meta-gabbro, a garnet gneiss and a monzonite (?) body were mapped.

The rocks uniformly trend east-northeast with near vertical dips; local variations resulting from drag folds are rare. However, two large anticlines were found within the mapped area; one with a wide area of gently dipping beds along the axis is proven and the other, a tight isoclinal fold, is tentatively inferred. The faults, shear zones, and dike rocks trend north-northwest, and cut the rock units at a large angle. One zone of faulting with discontinuous mineralized shears already has been traced 14,000 feet. A large unmapped area of breccia occurring along the southern margin of an intrusive stock of monzonite (?) was discovered at the close of the field season.

Thorium occurs along the north-northwest structural breaks. At places it is associated with barite, smoky quartz and abundant limonite; at other places it essentially occurs alone as veinlets or red stains. Spectrographic studies have indicated that small amounts of rare earths locally are present. As yet, no general relationship between the thorium and the country rocks has been definitely established; at Haputa Ranch the strongest radioactivity was associated with granitic rocks rather than mafic rocks.

Radioactive reconnaissance carried on this year in conjunction with the geologic mapping disclosed a large number of radioactive localities. More than 100 localities having radioactivity greater than 0.1 mr/hr (10 on the .2 scale of a Geiger-Mueller counter) were found along with 14,000-foot zone of faulting. A map showing the locations of all the radioactive localities will be transmitted as part of a preliminary summary report. The number of weakly radioactive localities is very large; the recently discovered monzonite body south of Grape Creek exhibits radioactive anomalies of 2 to 5 times background on a scintillometer (Nuclear Research's Radiation Survey Meter SM-3A) over a 1500-foot traverse along the southern edge.

It would be premature to hazard a guess as to the tonnage and grade of reserves at any locality other than the explored part of Haputa Ranch. The inferred ore reserves at Haputa Ranch, determined by diamond core drilling, are given in the table below.

Inferred tons of ThO_2 of two ore shoots, Haputa Ranch

Method of determination	0.6% ThO_2 cut-off	0.3% ThO_2 cut-off	0.1% ThO_2 cut-off
Barnaby logging	324.4	524.1	954.4
Equivalent ThO_2 from core samples	46.4	149.4	536.4

These reserve estimates should be considered preliminary because of (1) the discrepancies between chemical thorium, and radiometric analyses, and Barnaby results, and (2) the sparse information on the size and shape of the ore shoot within the deposits. Additional information on the derivation of the reserve figures will be given in a report on the results of the exploration program at Haputa Ranch.

The field work was recessed at the end of November and will be resumed about May 1, 1953. In addition to the report work and map compilation, an intensive petrographic study will be made of thin sections of the country rocks. With this petrographic foundation to supplement field experience gained during the first season, mapping can be expected to proceed at an accelerated rate during the next field season.

Lemhi Pass district, Idaho-Montana
by W. N. Sharp and W. S. Cavender

The ultimate objective of the current investigations in the Lemhi Pass district is to evaluate the thorium and related rare-earth resources. To accomplish this a program of geologic mapping, systematic sampling and radiometric reconnaissance in the region of Lemhi Pass was begun this year. An earlier report on the deposits by Trites and Tooker was transmitted as TEI-140.

During this report period an area of approximately 20 square miles was mapped on aerial photos (approximate scale 1:20,000), and small areas of particular economic or geologic importance were mapped in detail (scale 1:600 or 1:1,200) by plane table methods. In addition, several short mine adits were mapped in detail. Radiometric and geologic reconnaissance was carried out throughout the region. One locality, the Silver King group of claims, near Shoup, Idaho, is of particular economic importance and a preliminary report describing the massive monzonite in replacement vein deposits is in preparation. Two DMEA projects--Last Chance claims in Beaverhead County, Montana and Wonder Lake claims--were followed closely.

The Lemhi Pass district is in the Beaverhead Mountains, which is composed predominantly of quartzite and argillite of the pre-Cambrian Belt Series. Tertiary volcanics, flows, and pyroclastics overlie the rocks of the Belt series. The pre-Cambrian rocks are intruded by diorite (?) dikes.

Within the pre-Cambrian quartzites, along zones of structural weakness, the rocks have been effected by replacement veins composed mostly of massive quartz. These quartz veins which are the primary interest in this study, may be grouped into 4 classes, according to accessory minerals and possibly to other characteristics. These are (1) quartz-copper veins (2) quartz-barite-hematite-thorite veins, (3) quartz-hematite veins, and (4) quartz-copper thorite veins.

Quartz-copper veins

Quartz-copper veins mineralogically are white quartz veins that contain varying amounts of bornite, chalcopyrite, gold and the secondary minerals of copper and iron. These veins have been explored for possible ore grade material and several have been mined in the past. They are not normally radioactive.

Quartz-barite-hematite-thorite veins

Quartz-barite-hematite-thorite veins are composed of white to red-brown stained quartz containing zones rich in white to pink barite and evenly distributed thorite as small red-brown streaks, masses and stains. Specularite is common and the hydrous forms of iron oxide are abundant.

These veins and replacements are usually more highly fractured and are very radioactive.

Quartz-hematite veins

Quartz-hematite veins are not numerous. Composition is white massive quartz and black and red forms of iron oxide. Occasionally there is slight radioactivity and minor amounts of other accessory minerals.

Quartz-copper-thorite veins

Quartz-copper-thorite veins are few and may prove to be a thorite invasion of a primarily quartz-copper vein. Nevertheless they are given a place in this tentative grouping. Composition is quartz-bornite, chalcopyrite, pyrite, alteration products of copper and iron and substantial showing of thorite. Barite and iron and calcium carbonates may be locally common. The largest vein of this type is being explored thorugh DMEA support.

The ages of these quartz veins have not been established and their relationships have not been determined. A relationship between the radioactivity and the series of diorite dikes in the district is to be examined.

Results of sampling in Lemhi Pass district

Sampling for analytical work in the Lemhi Pass district included roughly 70 samples, all of which were quartz vein rocks. The results to date are conclusive in that the district is productive of thorium only, in the radioactive metals. No significant amounts of uranium have been noted. Small values in rare earths are standard. Copper was not evaluated although some of the rock contains significant amounts of this metal.

The Lemhi Pass district is potentially a source for medium-grade thorite-bearing material; reserves, based on incomplete data, are in excess of

140,000 tons of quartz rock containing 0.8 percent ThO . It is not a district that has any evidence of containing significant uranium concentrations. Rare-earth metals might possibly be recovered as by-products.

The possibility of finding other deposits of thorium-bearing material in the districts adjoining the Lemhi Pass is not remote. However, the locus of this mineralization seems to have been covered by the mapped district. No definite geologic boundary or limit has been established for this type of occurrence.

Geologic conclusions are pending compilation of maps and laboratory work on rock specimens.

The plans for future work in the Lemhi Pass district are limited. Present DMEA projects are to be continued in the spring of 1953, and this work may be observed. Aside from this, no further work is planned for the Lemhi Pass district at this time.

In the region, it is recommended that interest be directed to the Silver King Monazite claims, located north of Shoup, Lemhi County, Idaho. It is recommended that this district, called Mineral Hill, be mapped in a fashion similar to that done in the Lemhi Pass district, on aerial photos at a scale of 1:20,000. Additional mapping by plane table, at larger scale, of specific localities would supplement this small scale mapping.

The district, which is a pendant of metamorphic rocks, is well bounded by granitic rocks and is roughly 30 square miles in extent. The occurrence of monazite in baritic, carbonate replacement veins promises to furnish information of great academic and economic interest. Some development work was started on the deposits by the Simplot Company, in July 1952.

Central Idaho monazite
by J. H. Mackin and K. L. Buck

Geomorphic studies of Central Idaho placer monazite deposits were begun on behalf of the Commission in June 1952 in connection with the Bureau of Mines exploration program. The objective of the work is to define additional areas of ground favorable for monazite deposits.

The studies this summer were carried out in Long Valley and in Bear Valley, Valley County. The monazite deposits of the Long Valley district are fills in a north-trending depression formed by late Tertiary and Pleistocene faulting. The Idaho batholith was the source of the monazite which was deposited in the fault troughs by streams from the east. An early depositional unit, rotated westward by renewed faulting, has been eroded into rolling topography along the east side of the basin. In the western part of the basin the downtilted portion of the early unit is deeply buried by a later depositional unit. The monazite deposits then form a composite wedge thickening westward to perhaps several thousand feet. The monazite content at depth will depend upon the type of sedimentation in that part of the wedge and can be determined only by drilling (TEM-473).

The Bear Valley deposits are very similar in origin and structural relations. A preliminary report on the Bear Valley placers will be transmitted within the month.

Plans for the next six months call primarily for the completion of a final report after which the Survey has no further plans for geomorphic work in Central Idaho. If, after receiving the report on Bear Valley, further work is deemed necessary by the Commission, plans for field work will be made by the Survey for the next field season.

REGIONAL RECONNAISSANCE FOR URANIUM AND THORIUM

IN THE UNITED STATES

The objectives of the regional reconnaissance in the United States are: (1) to search for new uranium and thorium deposits based on geologic relationships; (2) to make detailed examinations of selected uranium- and thorium-bearing deposits; (3) to make reconnaissance and detailed examinations of uranium occurrences reported by the public, or requested by the Commission and Survey -- particularly requests for advice on DMEA loan applications.

The fundamental approach to objective (1) is to search for new deposits on the basis of lithologic occurrence in relation to the regional geologic picture-searches guided primarily by knowledge of geologic guides to and habits of deposits of a specific lithologic type. On this basis, most of the work is focused on reconnaissance of areas in which no trace elements investigations are in progress but which are regarded as broadly favorable for the occurrence of radioactive deposits.

This work is being conducted in the nine districts of the Survey's Mineral Deposits Branch that are divided geographically into the: Northeastern, Southeastern, South-Central, and North-Central states, Colorado-Wyoming, Arizona-New Mexico, Utah-Nevada, Northwestern states, and California. The activities in each of these districts during the report period are discussed below.

Northeastern states

by F. A. McKeown and Harry Klemic

A systematic search for radioactive materials in mining districts of the northeastern states was begun in July 1952. As is well known, mining activity over a period of two centuries in this region has demonstrated the existence of innumerable deposits of many different types of minerals in a great variety of geologic settings. Therefore, deposits of radioactive substances, not hitherto sought except in a desultory manner, may remain to be discovered among these mineral provinces. The overall task involves assembling data on known occurrences, including a comprehensive search of published information, systematically investigating in the field the geological types of deposits that theoretically might contain uranium or thorium, digesting the results, and interpreting them as to geologic and economic potentialities.

From July to November 1952, approximately 60 percent of the time was spent in field work, 15 percent in scanning the literature and 25 percent in office and laboratory work pertaining directly to the field studies. The bulk of the field work was devoted to systematic examination of magnetite deposits in New York, Pennsylvania and New Jersey, prompted by the known association of uranium with titanium at Mozambique, Africa, and Olary, South Australia, and by the fact that the iron-ore deposits of the northeastern states lie within areas previously known to contain radioactive rock.

In addition to the magnetite deposits, several lead-zinc, copper and molybdenum deposits in Aroostook County, Me.; 3 greensand deposits in Burlington County, N. J.; and several copper and chromium deposits in

Franklin, Adams, and York Counties, Pa. were radiometrically examined.

One hundred and eleven mines, prospects, quarries, mineral localities and slag dumps of old iron furnaces were radiometrically examined. Rock, iron ore and slag containing more than 0.005 percent equivalent uranium were found at 22 of these localities. Five of them contain radioactive and rare earth-bearing material that may be of economic or mineralogic interest. The available data indicate that the most significant discovery is the rare earth and thorium content of the tailings from the "Old Bed" magnetite deposit at Mineville, N. Y. The "Old Bed" is an apatite-rich magnetite ore. Tailings from it contain from 0.10 to 1.0 percent cerium, lanthanum, and yttrium; 0.004 percent uranium; and probably about 0.03 percent thorium. These elements probably are in the apatite, most of which is concentrated in the tailings. About 1,300 tons of the "Old Bed" tailings are produced daily and several hundred thousand tons are in old tailings piles. Analyses and office compilation of data are needed before the "Old Bed" tailings and other occurrences of radioactive material examined last summer can be further evaluated.

Other significant results of the field work, as interpreted in advance of chemical analyses yet to be completed have been summarized in TEM-551, "Preliminary report on reconnaissance for radioactive materials in the northeastern United States", by Frank McKeown and Harry Klemic.

Plans for the next 6 months are contingent to some extent on laboratory results. Tentatively, however, they are: (1) to prepare for and start in early spring a regional reconnaissance of eastern Pennsylvania and New Jersey. This will consist essentially of examining lead, zinc, and copper deposits, supplemented with some radiometric car traversing. The mineral deposits within and bordering the Triassic formations of Pennsylvania and New Jersey lie within a belt of rocks of diverse composition about 75 miles wide and 200 miles long; Newhouse (Econ. Geol., 1933, p. 613) has pointed out the apparent zoning of iron and copper deposits in the Triassic rocks; and there are many occurrences of radioactive minerals and anomalies. These features suggest that this area may be favorable for prospecting for uranium deposits. (2) Arrangements may be made to obtain some details of the geology of the Mineville district from the Republic Steel Corp. to supplement our information in a study of the rare earth-containing apatite. (3) Office and laboratory work will be continued at a reduced rate during the winter months.

Southeastern states
by H. S. Johnson, Jr.

The project for reconnaissance of the southeastern states was not begun until late September because of a lack of personnel. To date most work has consisted of library research, study of representative types of radioactive deposits elsewhere in the United States, particularly in South Dakota and the Colorado Front Range, and planning the field program.

Although it appears at this stage that the chances of finding new occurrences of radioactive materials in the southeastern states is quite promising, considerable work is necessary before a true evaluation can be made of the potentialities. Heretofore, very little in the way of systematic reconnaissance for uranium has been undertaken in many parts of the region, and there are large areas that have not been investigated at all.

Plans for the months to come are to make brief reconnaissance studies of areas where mining has been undertaken for gold, copper, zinc, lead, molybdenum, tungsten, iron, manganese and other minerals that might conceivably have uranium associated with them. Other areas where no mining has been done but where geology appears favorable will also be investigated.

South-central states
by J. W. Hill

Beginning in November the project chief contacted various personnel of the state geological surveys and other geologists in Missouri, Oklahoma, Texas, and Arkansas; and collected mineral samples of interest.

Of a total of 42 samples collected and received from interested persons, two samples with appreciable amounts of radioactivity were prominent: an "albertite" specimen from the Mine La Motte near Fredericktown, Missouri, and a group of asphalt pellets from the north flank of the Wichita Mountains in southern Oklahoma. Initial results from the Denver Trace Elements Laboratory showed that the "albertite" specimen contains 0.54 percent equivalent uranium and the asphaltic pellets contain 0.31 percent equivalent uranium.

The lustrous black "albertite" specimen was reported to have come from a small vug or crack along the sandy transition zone between the Cambrian Lamotte sandstone and the overlying Bonneterre formation. Occurrences of asphaltic minerals were reported to be relatively rare in the Fredericktown mines, the only mines in which "albertite" is known to occur in the south-central states.

The dull black asphaltic pellets are irregular and sub-rounded in appearance, varying in size from that of a pinhead to more than an inch in diameter. Information is lacking on the true distribution of these pellets, but they are reported to occur sparsely disseminated in one of the Permian "Red Beds", a bed less than two feet in thickness.

Plans during the next six months will be directed toward the screening, radiometric examination, and study of the material available from this area. Material such as well cuttings and gamma-ray logs are already available in the files of the various state geological surveys, oil companies, and mining companies.

As soon as sufficient field and laboratory information is available about the nature and extent of the known radioactive mineral deposits within this area, the information will be publicized to obtain full interest and participation by the public in the search for other deposits of radioactive minerals.

North-central states

by R. C. Vickers

The specific objectives for the reconnaissance work in South Dakota are: (1) the reconnaissance for radioactive materials in the mining areas of the northern Black Hills, (2) the reconnaissance for radioactive materials in the central part of the northern Black Hills, with special attention to Tertiary intrusive rocks, and (3) the delimitation of geologic areas of possible low-grade materials for more intensive investigation.

During July 1952, the above objectives for South Dakota were completed. A radiometric traverse was made of most of the old mine dumps in the central part of the northern Black Hills and most of the accessible highways were traversed with car-mounted equipment. The results indicated that some of the Tertiary intrusive rocks of the northern Hills are abnormally radioactive (as much as 0.014 percent equivalent uranium) and are among the most radioactive igneous rocks in the United States according to the available literature. Chemical analyses indicate that only a small percentage of the radioactivity is due to uranium. Chemical thorium analyses are being made of the more radioactive samples and because of the large tonnage of material present, petrographic and laboratory studies are in progress to determine the thorium mineral and to find out if the radioactive material can be easily concentrated.

During the reconnaissance in the northern Hills an occurrence of autunite was found near Foley Mountain in Lawrence County. The autunite occurs as fracture-fillings and disseminations in siltstone of the Cambrian Deadwood formation and was found mainly above a near horizontal contact of the siltstone with an underlying Tertiary rhyolite porphyry. Fluorite and limonite are closely associated with the autunite. The autunite is exposed only in an old short prospect adit, but abnormal radioactivity was also detected in a prospect pit 90 feet from the adit. Preliminary work indicates that the uranium may be present over a considerable area above the porphyry-siltstone contact. An 18-inch channel sample from the adit contained 0.048 percent equivalent uranium. Inferred reserves are 100 tons of rock containing 0.05 percent uranium, and 1,000 tons of rock containing 0.02 percent uranium. With the exception of the autunite in Lawrence County, no abnormal radioactivity associated with Teritary mineralization was detected in the northern

Black Hills.

The examination of the known occurrences of radioactive rocks in Michigan, Minnesota, and Wisconsin and a radiometric reconnaissance of favorable areas in those states were partly completed. Under the guidance of L. P. Barrett, AEC contractor, an examination was made of the following properties: 1) Huron River uranium prospect, Baraga County, Michigan; 2) Isham uranium prospect, Dickinson County, Michigan; 3) M & G uranium prospect, Marquette County, Michigan; 4) Sherwood mine pitchblende occurrence; 5) Gwinn district, Marquette County, Michigan, and 6) Palmer area, Marquette County, Michigan. During a conference with L. P. Barrett it was decided that the Geological Survey would undertake geologic studies of some of the Michigan radioactive occurrences. Because of commendable detailed reconnaissance and sampling program conducted in northern Michigan, no additional reconnaissance work was done.

Plans

During the next report period laboratory studies will continue on the relationships of the radioactivity elements in the Tertiary igneous rocks on the northern Black Hills.

During the winter laboratory work is planned on samples collected from the Huron River uranium occurrence and a final geologic report, in cooperation with L. P. Barrett, is planned. Petrographic and laboratory work will be done on specimens of the thorium-bearing Goodrich conglomerate, Marquette County, Michigan.

Work is now in progress to apply the geologic relationships of the Theano Point (Ontario, Canada) pitchblende deposits to possible occurrences in northern Michigan, Wisconsin, and Minnesota. Because of the close association of the Theano Point pitchblende to lamprophyre dikes, some work will be done this winter on the lamprophyre dikes in the Lake Superior region.

During the 1953 field season the following work is planned: (1) Detailed reconnaissance and geologic maping (scale 1:1200) of 1/2 square mile of the autunite occurrence in Lawrence County, South Dakota. (2) Geologic mapping (scale 1:6000) of one square mile in the Palmer area, Marquette County, Michigan to determine the distribution of the thorium in the Goodrich conglomerate and to appraise the tonnage and grade. Chemical thorium analyses have not been received at this time, but spectrographic analyses indicate a grade of 0.X percent thorium, 0.X percent each of Ce, La, and Nd. (3) Radiometric reconnaissance of the Wausau granitic area, Wisconsin. (4) Radiometric reconnaissance of the lamprophyre dikes in the Lake Superior region.

Colorado and Wyoming

by R. U. King

Nine localities in Colorado and four in Wyoming were examined for radioactivity during the first half of the year, and reconnaissance reports have been submitted on these localities. Of these localities, only the monazite-bearing conglomerate in Bald Mountain district, Sheridan County, Wyo., appears to be of commerical importance. The resources in this district are estimated to be 10 to 20 million tons of rock, containing 125 tons of thorium. The monazite content may amount to 2,500 tons. Further investigation of the deposits at Bald Mountain will depend on the results of a current Bureau of Mines exploration project.

Radioactive materials have been reported recently from 20 localities in Colorado and from one locality in Wyoming. It is planned to follow up those leads for which there is adequate information as to the geology and radioactivity.

The following districts are selected for future reconnaissance because of favorable mineral associations, and because of reported or known radioactive deposits in the districts:

(1) Gold Hill district, Boulder County, Colo.

(2) Manhattan and Masonville districts, Larimer County, Colo.

(3) Breckenridge-Montezuma-Argentine-districts, Summit County, Colo.

(4) Encampment and surrounding area, (including Pearl, Colorado) Carbon County, Wyo.

(5) Bighorn Mountains, northwestern part, in the vicinity of Bald Mountain, Sheridan County, Wyo.

Arizona-New Mexico
By R. B. Raup

At the request of the DMEA office in Tucson, Arizona, two uranium deposits were evaluated in connection with loan applications. The Red Bluff claims about 10 miles north of Grants, N. Mex., were examined briefly. Reserve and average grade estimates were estimated by the DMEA field team but were insufficient to warrant approval of the loan. An examination of the Rainbow claim 23 miles west of Fredonia, Arizona was also made for DMEA. Inferred reserves are 1200 tons of rock containing 0.024 percent uranium.

An examination of the White Oak property in Walker Canyon, just off the Ruby road, 16 miles northwest of Nogales, Arizona, was made at the suggestion of the AEC. This deposit of secondary lead and uranium minerals in a shear zone in Tertiary (?) rhyolite porphyry contains an inferred reserve of 5 to 10 tons of material containing 0.47 percent uranium. The report on the deposit, "A lead-uranium deposit at the White Oak No. 1 mine, Santa Cruz County, Arizona" (TEM-511), recommends no further exploration because the possibilities of large deposits are not good.

The Tomcat claims northwest of the Castle Dome open pit near Superior, Ariz., the Abril mine in the Dragoon mountains east of Tombstone, Ariz., and dumps in the Patagonia mining district east of Nogales were checked radiometrically. No abnormal radioactivity was found.

An evaluation of the uranium potential of the area R. 1-22 W., and Gila Bend, Ariz., to the Mexican border has been requested by the U. S. Air Force but has been postponed until the winter months.

Individual properties that merit special attention because they are known to contain uranium are the Black Dike claim, 40 miles west of Tucson, and the Hillside mine near the Bagdad, Ariz. copper deposit. Occurrences of uranium that have never been located and studied are reported in the Tombstone area and the Santa Rita mining district, Ariz.

Special projects planned are the reconnaissance for radioactive materials in the Yuma desert area in southwest Arizona, as mentioned above, and in the San Carlos Indian reservation. Also, a ground check of airborne scintillometer anomalies in the Grants, New Mexico, area may be necessary in December 1952 or January 1953.

Utah-Nevada
by A. O. Taylor

The following prospects, areas, and mining districts in Utah and Nevada were reconnoitered during the report period. (* Indicates a locality known to contain uranium.)

1. Tushar mountains*, Beaver County, Utah.
2. Wah Wah mountains*, Beaver County, Utah.
3. Needle mountains*, Beaver County, Utah.
4. San Francisco district, Beaver County, Utah.
5. Mineral mountains*, Beaver County, Utah.
6. Goodsprings district*, Clark County, Nevada.
7. Muddy mountains*, Clark County, Nevada.
8. Drum mountains, Juab County, Utah.
9. Humboldt mountains*, Pershing County, Nevada.
10. Unionville district, Humboldt County, Nevada.
11. Cottonwood district, Salt Lake County, Utah.
12. Bingham Mining district, Salt Lake County, Utah.
13. Battle Mountain district, Lander County, Nevada.
14. Deep Creek mountains, Tooele County, Utah.
15. Little Erma No. 2 prospect*, Emery County, Utah.
16. Markagunt plateau (western edge), Iron County, Utah.
17. Sorensen Uranium prospect*, Millard County, Utah.
18. Sloan district*, Clark County, Nevada.
19. Sutor district*, Clark County, Nevada.
20. Buffalo district*, Churchill County, Nevada.
21. Atlanta district*, Lincoln County, Nevada.
22. Yerington area*, Lyon County, Nevada.
23. Toquima range*, Nye County, Nevada.
24. Antelope district*, Pershing County, Nevada.
25. Crescent district, Clark County, Nevada.

Areas 1, 2, 9, 10, 11, 12, 13, 15, 16, and 17 were examined as of November 30. Areas 10, 11, 12, 13, and 16 were entirely negative, meaning that no <u>abnormal</u> concentrations of uranium were found. The other areas studied, 1, 2, 9, 15, and 17, contained uranium deposits. The principal results of the work are described below:

Tushar mountains, Beaver County, Utah

The Mystery-Sniffer claims are in sec. 28, T. 27 S., R. 6 W., SLM, on the western slope of the Tushar mountains. The uranium deposit on the claims is essentially a tabular body composed of highly altered rhyolite and latite containing pyrite, quartz, fluorite, and uranium. The uranium is in the minerals autunite and torbernite. The vein, or tabular body, strikes generally east-west, dips 35-70 degrees north, and ranges in thickness from 10 to 65 feet. Preliminary estimates of inferred grade and tonnage of uranium-bearing material exposed to date by exploratory work are:

Reserves (Short tons)	U_3O_8 (percent)	U_3O_8 (Short tons)
230,000 (total)	0.019	45
30,000 (included in total)	0.08	24

More than half of the uranium is contained in 13 percent of the estimated total tonnage and is in that part of the vein that is topographically lowest. The eU/U ratio varies from 3 at the highest part of the vein to 1 at the lowest exposed part of the vein. These facts may be explained by a selective leaching and separation of uranium from its daughter product radium, in the upper part of the vein. Assuming this explanation to be the correct one, an increase in grade may be expected below the zone of leaching. Judging from the similarity of this deposit to the uranium deposits at Marysvale, Utah it is probable that pitchblende will be found in the vein below present exposures. The potential of this deposit with respect to eventual production of uranium ores is believed to be good.

Three undeveloped uranium prospects, the KO, Canary, and H & H, are in secs. 10, 16, and 21, T. 28 S., R. 6 W., SLM, Beaver County, Utah.

Disseminations of autunite and torbernite are found in argillized and silicified Tertiary volcanic rocks at all three prospects. Exposures are insufficient to permit estimates of reserves and grades. The noteworthy feature of these prospects is that they are geologically and mineralogically similar to the uranium deposits at Marysvale and to the deposit at the Mystery-Sniffer claims.

The Baldy uranium prospect is in unsurveyed sec. 6, T. 28 S., R. 5 W., SLM, Beaver County, Utah. The deposit is a highly brecciated rhyolite cemented with iron oxides. Clay minerals apparently underlie the breccia. The breccia is bounded by a strong footwall fault zone that strikes N. 20° E and dips 80° west. The width of the mineralized zone normal to the strike of the footwall fault zone is about 65 feet. Radiometric readings as high as ten times background were obtained but samples assayed only 0.001 to 0.005 percent U_3O_8. The ratio eU/U varies from 6 to 2.5 which may indicate that uranium has been selectively removed from its daughter product radium. The deposit is about four miles from the nearest road in mountainous country that is subject to heavy winter snowfalls. A flow of water estimated to be more than 200 gallons per minute is issuing from the fault zone. No specific uranium minerals were observed in this deposit.

Wah Wah mountains, Beaver County, Utah

The Staats fluorite mine is in secs. 25 and 36, T. 29 S., R. 16 W., SLM in the southern part of the Wah Wah mountains. The mine may be reached by road from Milford or Lund, Utah. Irregular veins and lenses of fluorite are in the border zone of an altered quartz porphyry that intrudes Paleozoic limestone. The contact of the quartz porphyry and limestone is intricately faulted and much brecciated. Autunite is associated closely with fluorite that is dark purple in color. The deposit also contains light green and white fluorite that is non-uraniferous for all practical purposes. About 3500 tons of metallurgical grade fluorite has been produced from the deposit. Most of the old workings are now inaccessible; consequently no ore reserve estimates were made. A DMEA exploration program for fluorite and uranium is now under way. The potentialities of the deposit as a source of uranium will be evaluated at the conclusion of the exploration program.

Humboldt mountains, Pershing County, Nevada

Stalin's Present prospect, sec. 6, T. 29 N., R. 34 E., Mt. Diablo Meridian, was visited briefly in connection with an application for a DMEA loan. The deposit is a vein enclosed in silicic igneous rock. The vein minerals include hornblende, diopside, chlorite, biotite, epidote, quartz, calcite, pitchblende, and gummite (?). The workings in the deposit consist of a short adit and a winze 47 feet deep, which was put down on the best showings of uranium ore exposed in the adit. The uraniferous vein material pinches, and passes into the west wall of the winze a short distance below the collar. The bottom of the winze is barren of uranium minerals. Although reserves are small, the presence of pitchblende makes this deposit of interest. It is probable that new deposits can be found by detailed study of the surrounding area.

Little Erma No. 2 prospect, Emery County, Utah

The Little Erma No. 2 claim is in sec. 24, T. 25 S., R. 10 E., SLM. The claim can be reached via an unimproved road by traveling 7.5 miles southwest from Temple Mountain, Utah to the head of Chute Wash. Uranium ore has been exposed near the base of the Shinarump formation of Triassic age. The uranium minerals are pitchblende and its secondary alteration products. Associated minerals are pyrite, chalcopyrite, galena, sphalerite, unidentified arsenides or sulpharsenides of cobalt and nickel, and hydrated sulphates and arsenates of copper, nickel, and cobalt. The pitchblende, sulphides, and arsenides or sulpharsenides are present as impregnations of porous sandstones and as replacements of carbonized plant remains and a black resinous substance having the appearance of a hydrocarbon. The sulphates, arsenates, and secondary minerals of uranium are present as coatings and efflorescent incrustations on the walls of joints and exposed rock surfaces. Inferred ore reserves are 230 tons containing 0.12 percent U_3O_8. Vanadium is practically absent in the ore. The possibility of finding more ore by exploration is good.

Sorensen uranium prospect, Millard County, Utah

The Sorensen No. 1 claim is in sec. 10, T. 23 S., R. 14 W., SLM. An unidentified, yellow, non-fluorescent, uranium mineral is present in a fault zone between Paleozoic quartzite and limestone. The grade of selected material is less than 0.005 percent U_3O_8. The deposit has little potential for production of uranium ores.

The general results of the field work and observations are listed below:

1. Uranium is very frequently associated with dark purple fluorite in Utah; all deposits of fluorite in Utah and Nevada should be closely examined.

2. Areas having Tertiary volcanics with rhyolitic members and monzonitic to granitic intrusive rocks appear to be particularly likely to contain uranium deposits in Utah and Nevada.

Work planned for the future includes delineation and evaluation of uranium-bearing areas in the localities previously listed at the beginning of this section that have not yet been studied. In addition it is planned to make further study of the geochemical factors that affect the concentration of uranium. This study will be concentrated on southcentral and southwestern Utah and southeastern Nevada because this region is most favorable from the standpoint of abundance of uranium and fluorite and petrographic associations. Such a study is desirable, in fact necessary, to reduce to a minimum the element of randomness in the search for and appraisal of radioactive deposits in the region.

Northwestern states

by F. C. Armstrong

The following DMEA exploration programs were investigated during the period.

A quartz-barite vein containing thorite and specularite has been exposed by several trenches at the Last Chance thorium area, Beaverhead County, Mont. Two diamond drill holes have intersected the vein at depth;

three holes remain to be drilled. The third hole was discontinued at about 90 feet because of inclement weather, but the project will be continued next spring. Analyses of the samples from the first two holes are not yet available.

Trenching has exposed a thorite-bearing shear zone containing a little quartz at the Defense Metals thorium, Lemhi County, Idaho. Work has been discontinued for the winter. It has been decided to amend the DMEA contract by reducing the amount of diamond drilling originally proposed, and instead, drift on the zone in the spring.

The Cosumnes Gold Dredging Co. has two DMEA contracts: at Paddy Flat, and at White Hawk Basin, both in Valley County, Idaho.

Thirty-five holes have been drilled in the Paddy Flat monazite placer. An old channel has been located, the sands of which contain what appear, on preliminary examination, to be economic concentrations of monazite and magnetite. The heavy minerals and the different fractions of the heavies are being separated. Concentration methods for the sands are also being investigated, but results are not yet available. If the results prove favorable, more holes will be drilled to delimit the deposit; and a plan of operation will be formulated in preparation for working the deposit with a bucketline dredge.

Only the first phase (building an access road and drilling ten holes) of the DMEA contract was completed at the White Hawk Basin monazite placer before bad weather stopped work until next spring. The heavy minerals in the samples are to be concentrated and the various fractions separated. Results are not yet available. If the results are favorable, more holes will be drilled next spring in an effort to delimit a deposit of economic interest.

Drilling in Bear Valley, Valley County, Idaho indicated the presence of euxenite and samarskite in the sands in the valley. Work by J. Hoover Mackin of the U. S. Geological Survey has thus far shown that the best concentrations of euxenite and samarskite occur near Big Meadow on the east side of Bear Valley. It is not known what work is contemplated in Bear Valley for next field season, but sampling of the gravels may be continued.

Much of the winter will be spent in the study of regional geologic relationships in the Northwest with the purpose of finding areas favorable for reconnaissance next field season, and in becoming more familiar with the known radioactive occurrences in the Northwest. DMEA work on radioactive materials in the Northwest will be followed as required. It is anticipated that several applications for loans on placer deposits in central Idaho will be received during the winter.

California
by G. W. Walker

Field work during the period covered by this report consisted of geologic and radiometric examinations of 7 individual properties in California, including the Davis property, Madera County, Stillwell property and Rountree property, Kern County, Red Devil claim, San Bernardino County, Gen. U. S. Grant mine, Tuolumne County, and the Stowell property and Stokes property in Plumas County. Evaluations were made of the Stalin's Present claims, Pershing County, Nev. and the Osborn and Bassman property, Lyon County, Nev. for the DMEA. The Rosamond prospect, Kern County, Calif. was also considered regarding a DMEA loan. In addition, 15 other mining properties located principally in Calaveras and San Bernardino Counties, Calif. were checked radiometrically during DMEA examinations by geologists in the course of other work.

Preliminary Reconnaissance Reports were transmitted on the 7 properties examined both geologically and radiometrically; reports were completed on those properties examined for the DMEA and a report entitled "Rosamond prospect, Kern County, California" by George W. Walker is being prepared for transmittal to the Commission. Petrographic studies were completed on specimens collected in the Rock Corral area, San Bernardino County, and a report on the geology and occurrence of radioactive minerals in the area was pompleted that will be part of a more extensive paper by R. M. Moxham and G. W. Walker, in which the relationship of the geology of the Rock Corral area to "strong" radioactive anomalies detected by an airborne recording scintillometer will be described.

Work during the period was so diversified that the overall results of reconnaissance in California cannot be fully evaluated at this time. Examinations of individual properties has uncovered only small tonnages of weakly radioactive rock; under present conditions probably none of the properties constitute potential sources of uranium or thorium. On the other hand, data gained from these examinations, and from earlier examinations of properties in California, suggests: (1) a spatial relationship between many occurrences of secondary uranium minerals and areas underlain by Tertiary volcanic or near-surface intrusive rocks and (2) that some acid flows and intrusives have a slightly higher content of uranium than other rock types exposed in mineralized areas.

Petrographic studies of specimens from the Rock Corral area indicate that most of the abnormal radioactivity in the area is due to the relatively high content of allanite in a porphyritic quartz monzonite and included metasomatically altered, biotite-rich blocks. Point-count petrographic analyses of specimens of the monzonite yielded a content of as much as 4.5 percent allanite; one biotite-rich inclusion contained slightly more than 7 percent allanite. The porphyritic quartz monzonite and the biotite-rich inclusions contain variable amounts of zircon, apatite, sphene, xenotime (?), and many other mineral species. Some varieties of the zircon, and probably some apatite, sphene, and xenotime (?) add to the total radiation of the area.

Plans for work during the next period include: (1) examination of properties referred to the Reconnaissance Group, to the Commission, or to the San Francisco office of the Survey by prospectors or other individuals, (2) examination and evaluation of properties for the DMEA; (3) radiometric checks of all ore, rock, and mineral specimens in collections at the California State Division of Mines and at the University of California, and (4) reconnaissance examinations of the Chocolate Mountains-Cargo Muchacho area, Imperial County and Modoc Plateau area, Modoc County; both areas contain extensive exposures of Tertiary volcanic rocks.

If time permits, some reconnaissance work will be done on the distribution and concentration of radioactive minerals in the crystalline rocks exposed in the Gabilan Mesa area, Monterey County, Calif. Rocks from this area are known to contain radioactive accessory minerals; however, no work has been done on the distribution of these minerals.

REGIONAL RECONNAISSANCE FOR URANIUM

AND THORIUM IN ALASKA

by Helmuth Wedow

Introduction

The primary objective of reconnaissance in Alaska is the discovery of high-grade uranium ores. The appraisal of uranium possibilities of Alaksa in fiscal-year 1951 (TEM-235) indicated that many mineral deposits in the Territory were favorable for the occurrence of uranium because they contain assemblages of minerals characteristic of uranium deposits in other regions of the world. In fiscal-year 1952, 30 of these favorable deposits were examined for radioactivity (TEM-319, 320, 321, 322, 355, and 356; TEI-220 and 221). Although only 2 of the 30 localities appeared to be promising enough to warrant additional study, some 25 or more areas or deposits, believed to be favorable in the 1951 appraisal, remained untested. In fiscal-year 1953, therefore, the program of examining deposits with favorable mineral assemblages was continued. In addition, a few new leads to uranium occurrences were obtained through information or samples received from prospectors or government agencies. In all, 42 areas or deposits in Alaska were examined for radioactivity in fiscal-year 1953.

Reconnaissance in 1952

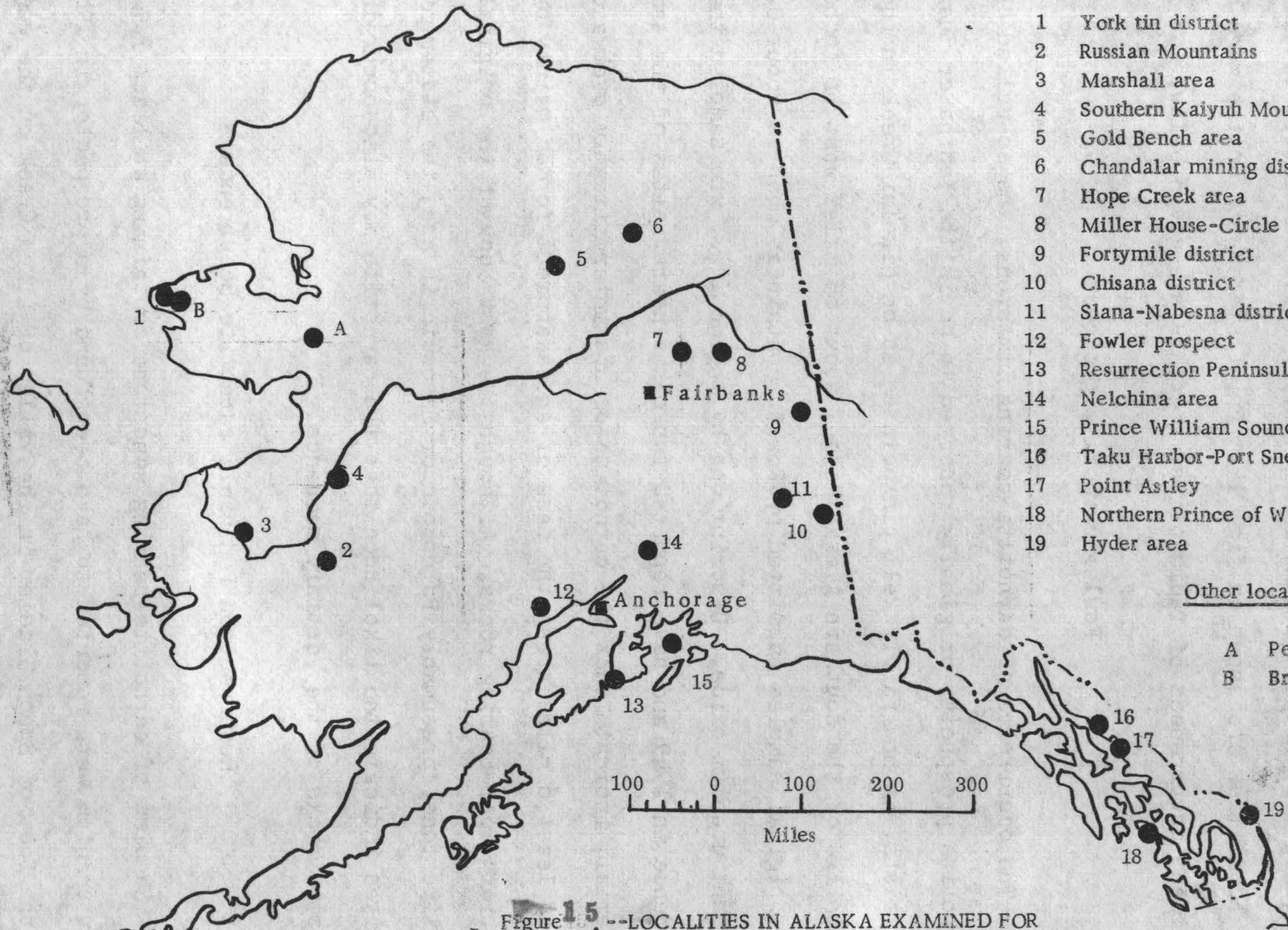
Reconnaissance in the period June 1 - November 30, 1952 centered chiefly in parts of the Lower Yukon-Kuskokwim region and northeastern, east-central, south-central, and southeastern Alaska. In addition, radiometric tests were made by regular Geological Survey parties conducting other investigations in the York tin district, the Nelchina area, and the Prince William Sound region. The preliminary results of all reconnaissance for the period June 1 - November 30 are summarized in table 8. The localities are shown on fig. 15. Brief statements on the more significent occurrences of radioactive materials are given below.

Fowler carnotite prospect

The occurrence of carnotite-bearing limestone, the so-called "Fowler carnotite prospect", originally reported to be in the Yentna or Susitna districts, is now fairly well pin-pointed as on Nikolai Creek in the foothills of the southern Alaska Range, about 65 miles west of Anchorage. The original samples submitted by Fowler contain as much as about 0.6 percent uranium oxide. Descriptions by the natives, who sampled the occurrence in 1949 and have reported two other nearby sites of the same material, indicate that the carnotite occurs intermittently over a distance of at least 6 miles along the base of an escarpment formed mainly by Tertiary coal-bearing rocks. Although the host rock of the original samples is limestone, presumably Paleozoic or Mesozoic in age, the statements of the natives indicate the likelihood that the carnotite may also occur in the clastic rocks of the Tertiary sequence.

Resurrection Peninsula carnotite occurrence

Samples of carnotite-bearing sandstone containing at least 1.7 percent uranium were reported to have been found by a prospector in 1949 at the foot of Spoon Glacier in the valley of Likes Creek on the west



EXPLANATION

Localities examined in the period
June 1 - November 30, 1952

1 York tin district
2 Russian Mountains
3 Marshall area
4 Southern Kaiyuh Mountains
5 Gold Bench area
6 Chandalar mining district
7 Hope Creek area
8 Miller House-Circle Hot Springs area
9 Fortymile district
10 Chisana district
11 Slana-Nabesna district
12 Fowler prospect
13 Resurrection Peninsula
14 Nelchina area
15 Prince William Sound
16 Taku Harbor-Port Snettisham area
17 Point Astley
18 Northern Prince of Wales Island and vicinity
19 Hyder area

Other localities mentioned in text

A Peace River area
B Brooks Mountain

Figure 15. --LOCALITIES IN ALASKA EXAMINED FOR RADIOACTIVITY IN THE PERIOD JUNE 1 - NOVEMBER 30, 1952

side of Resurrection Peninsula, about 9 miles southeast of Seward. The area surrounding the supposed carnotite site is underlain by lava flows now altered to greenstone. Clastic sedimentary rocks are known to occur in minor amounts within the greenstone and in grosser amounts elsewhere on Resurrection Peninsula and adjacent islands. Copper lodes have been found in the greenstone and pitchblende has been reported by prospectors on the east side of the peninsula.

Northern part of Prince of Wales Island and vicinity

Reconnaissance in the northern part of Prince of Wales Island and vicinity, southeastern Alaska, found that the radioactive carbonate-hematite veins in the Salmon Bay area (TEM-356) are probably limited in areal extent to that part of the island's coast from near Exchange Cove to Point Colpoys. The radioactivity of the veins at the surface appears to be due almost entirely to thorium; they contain a maximum of about 0.1 percent equivalent uranium with an average of about 0.03 percent equivalent uranium. The veins range in width from a fraction of an inch to about two feet and are rarely more than several hundred feet in length. Both the radioactive carbonate-hematite veins and some larger, essentially nonradioactive, carbonate veins contain minor amounts of rare-earth fluo-carbonates.

Gold Bench area

Uranothorianite is associated with hematite and traces of bismuth, copper, lead, tin, and tungsten minerals in placers at Gold Bench in the Koyukuk-Chandalar region, northeastern Alaska; one concentrate obtained in 1952 from placer operations at Gold Bench contains as much as 0.18 percent equivalent uranium. The association of the uranothorianite with the metallic minerals suggests a nearby lode source, possibly a vein, for these minerals. The source of the gold in the Gold Bench placers, and hence probably that of the uranothorianite too, is believed to be in the hills on the south side of the South Fork of the Koyukuk River above Gold Bench.

Tentative plans

In the period December 1, 1952 - May 31, 1953 final reports on the investigations of the 1952 field season will be completed and transmitted. Field work will be initiated in the early part of June 1953 on projects scheduled for fiscal-year 1954. The tentatively scheduled field projects are as follows:

Southern Alaska Range reconnaissance and mapping

Mapping and sampling of the reported carnotite occurrences on Nikolai Creek (Fowler prospect, no. 12, fig.15) in the southern Alaska Range will constitute the initial phase of this project. If studies in the first month of field work yield expected results, it is anticipated that a trenching, and possibly drilling, program will be recommended to be started as soon as possible after the beginning of the new fiscal-year. Paralleling the possible exploration program, the surface reconnaissance phase of the project will continue and be extended to adjacent areas in the region to determine the areal extent and geologic setting of the uraniferous deposits. If new samples of the uraniferous rock are not submitted by the prospectors during the coming winter in verification of this occurrence of carnotite, this project will be eliminated and such reconnaissance as may be necessary in the region assigned to the general reconnaissance project (see below).

General reconnaissance

The general reconnaissance project of the Alaskan program will search for the bedrock sources and make detailed appraisals of the Resurrection Peninsula carnotite (no. 13, fig. 15), the Gold Bench uranothorianite (no. 5, fig. 15), the uranothorianite and gummite at the headwaters of the Peace River (locality A, fig. 15), and of another Alaskan carnotite occurrence, details of which have not yet been disclosed by prospectors. Field appraisals of new leads will also be made as they develop. Companies may conduct further exploration, possibly by drilling, of the thorium-bearing veins on Prince of Wales Island (no. 18, fig. 15), southeastern Alaska, and of the zeunerite deposit on Brooks Mountain (locality B, fig. 15), Seward Peninsula. The Survey will maintain as close contact with these operations as is necessary to acquire a better understanding of the nature and grade of the deposits and to determine the potentialities of these deposits.

Fairbanks laboratory

The Radioactivity Testing Laboratory, located on the campus of the University of Alaska near Fairbanks, was open from about mid-June through early October 1952. During this period 623 equivalent uranium determinations were made, of which 65 were on samples submitted by prospectors.

Other work included 254 specific determinations of minerals and 580 individual element determinations with a visual spectroscope on both Survey and public samples. It is planned to reopen the laboratory in early June 1953 for the summer.

Table 8.--Preliminary summary of results of reconnaissance for uranium and thorium in Alaska during the period June 1 - November 30, 1952

Region Locality	Designation on figure 15	Type of deposit examined, sought for, or reported	Maximum radioactivity noted in samples from each locality: Equivalent uranium (percent)	Uranium (percent)
Seward Peninsula				
York tin district	1	Radioactive minerals in tin placers at Cape Mountain and in lodes at the Lost River tin mine	0.005 (est).	---
Lower Yukon-Kuskokwim region				
Russian Mountains	2	Zeunerite-bearing copper lode	0.004	---
Marshall area	3	Molybdenum-copper-lead lode	0.001	---
Southern Kaiyuh Mountains	4	Molybdenum lode	0.003	---
Northeastern Alaska				
Gold Bench area, Koyukuk-Chandalar region	5	Source of uranothorianite and associated bismuth, copper, lead, tin, and tungsten minerals in placers	0.18	---
Chandalar mining district	6	Metalliferous veins and source of monazite in placers	0.001	---
East-central Alaska				
Hope Creek area, Circle quadrangle	7	Quartz-pyrite-fluorite veins in tourmaline granite	0.055	---
Miller House-Circle Hot Springs area, Circle quadrangle	8	Fluorite-bearing granite rock	0.01	---
Fortymile district	9	Reported fluorite prospects	0.003	---
Chisana district	10	Copper, silver, and molybdenum lodes	0.004	---
Slana-Nabesna district	11	Copper, silver, and molybdenum lodes	0.004	---

Table 8.--Preliminary summary of results of reconnaissance for uranium and thorium in Alaska during the period June 1 - November 30, 1952 (con't)

Region Locality	Designation on figure 15	Type of deposit examined, sought for, or reported	Maximum radioactivity noted in samples from each locality Equivalent uranium (percent)	Uranium (percent)
South-central Alaska				
Fowler prospect	12	Carnotite-bearing limestone in prospector's samples	0.3	0.54
Resurrection Peninsula	13	Carnotite-bearing sandstone in prospector's samples	1.5	1.7
Nelchina area	14	Rocks and ores of different types and ages	0.001	---
Prince William Sound	15	Copper and gold lodes; hematite occurrences; various granitic masses and contact zones	0.003	---
Southeastern Alaska				
Taku Harbor-Port Snettisham area	16	Rumored pitchblende (?) lodes reported by the U. S. Bureau of Mines	0.003	---
Point Astley	17	Silver-copper lode	0.006	---
Northern Prince of Wales Island and vicinity	18	Radioactive carbonate-hematite veins, and copper, silver, lead, zinc, and molybdenum lodes	0.095	0.003
Hyder area	19	Pitchblende (?) in vein samples submitted by the Territorial Department of Mines	0.035	---

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ANALYTICAL SERVICE AND RESEARCH ON METHODS

Analytical Service
by J. C. Rabbitt and Jack Rowe

Tabular data pertaining to routine analytical work completed during the period June to November are listed below.

Table 9.--Analytical work and sample inventory, June-Nov. 1952

Project or material	Chemical determinations		Spectrographic determinations	Radiometric determinations	Samples received	Samples on hand at end of month
	Uranium	Other				
Washington Laboratory						
Southeast phosphate	2809	165	4728	8266	15032	9575
Lignite, coals, shales	637	736	10881	659	2993	2362
AEC, New York	147	17	4964	---	283	55
AEC, Washington	60	---	---	63	66	---
Northwest phosphates	114	770	14835	282	790	54
Fresh waters (P. F. Fix)	44	---	---	---	63	29
Sea waters (Gould)	123	---	---	---	103	---
Miscellaneous waters	---	6	---	177	204	25
Southeast monazites	---	---	1836	---	1543	1527
Miscellaneous	224	117	16,431	204	1169	181
Geochemistry of U	328	414	18,032	75	435	319
Total	4,486	2,225	71,707	9,726	22,681	14,127
Denver Laboratory						
Colo. Plateau deposits	655	2174	8350	1403	1456	303
Colo. Plateau plants	2237	2344	382	57	3746	1644
Oil well drilling	22	41	300	339	276	94
Southeast phosphates	948	---	---	3673	6	1348
AEC samples	1016	523	1967	1138	1188	46
Reconnaissance samples	967	1603	40,608	1323	3132	1880
Lignites	627	425	876	485	675	132
Miscellaneous	175	269	3592	244	394	191
Northwest phosphate	17	165	1176	81	292	---
Total	6,664	7,544	57,251	8,743	11,165	5,638
Grand Total	11,150	9,769	128,958	18,469	33,846	19,765

Research on methods

Chemistry
by F. S. Grimaldi

In previous reports the research work in chemistry has been described under major headings such as "Methods of uranium and thorium analysis", and so forth. This work henceforth will be described under respective research study headings and the old headings will be dropped.

Stabilities of dilute solutions of U, Th, and Pb on storage in glass and polyethylene bottles, by R. G. Milkey

Problem.--We are required frequently to determine trace amounts of U, Th, and Pb. In some cases the sample itself is a very dilute solution of these metals (i.e., natural waters). In other cases dilute solutions are prepared during the course of an analysis. We also regularly prepare standard solutions of these metals for standardization purposes. There is always the question of how stable such solutions are. This is important because weeks or months may elapse between the time water samples are collected and analyzed. Similar considerations hold for prepared solutions.

Glass is not an ideal vessel for shipping water samples. It can also contaminate the water due to the solubility of glass. Polyethylene containers presumably would cause less contamination and present no breakage problem in shipping. All studies therefore are being made in both glass and polyethylene bottles for comparison purposes.

Scope.--1. Effect of acidity

2. Effect of concentration of the metal ions

3. Relative stability of solutions in pyrex and polyethylene bottles.

Method.--Nitric acid solutions of the various metals at several levels of concentration and pH values were prepared. The levels of concentration for each metal ion varied from 0.1 gamma per ml to 1000 gamma per ml and the pH varied from 0 to 6.5. Approximately half the volume of each solution was placed in a glass bottle, and the other half was placed in a plastic bottle, and the bottles were tightly sealed. After the solutions had remained undisturbed for a period of two months, they were then analyzed for the concentration of the metallic ion still remaining in solution.

Uranium solutions: Uranium was determined fluorimetrically: There appeared to be no appreciable change of uranium concentration in any of the solutions whose pH values ranged from 0 to 3.5. Solutions whose pH values ranged from 4 to 6.5 showed considerable loss (up to 50%) of uranium, both for solutions stored in glass and in plastic bottles. The loss also depended upon the concentration of uranium. When the solutions were shaken vigorously for 1 minute and retested, no significant gain in strength was noted.

Lead solutions: The lead concentration was determined by extraction with dithizone, followed by density measurements with the spectrophotometer. The only solutions showing loss of strength were those with original concentration of 0.1 microgram per milliliter, and pH between 5 and 6. Solutions contained in both plastic and glass bottles showed this loss, amounting up to 80% of the original concentration. When the solutions were shaken vigorously for 1 minute and retested, no significant gain in concentration was noted.

Thorium solutions: Sodium alizarin sulfonate was used for the determination of 50-200 gamma of thorium. 1-(o-arsonophenylazo)-2-naphthol-3,6-disulfonic acid was used in the analysis of the remaining, more dilute solutions.

It has been determined that all solutions of thorium with pH between 0 and 3 showed negligible loss in strength after standing undisturbed for two months. The remainder of the solutions, with concentrations from 1000 micrograms per milliliter to 0.1 microgram per milliliter, and pH from 4 to 7.0 are now in the process of being tested.

When the complete data have been assembled, they will be incorporated into a formal report on the stability of such solutions.

Investigation of colorimetric and/or fluorimetric reagents for the determination of thorium, by M. H. Fletcher

The original aims of this project were first, to find a very sensitive, and second, a specific reagent for the colorimetric or fluorimetric determination of thorium. As a first step, various organic compounds were tested qualitatively at seven pH levels for their colorimetric or fluorimetric reactions with thorium. They were also tested with zirconium because zirconium interference, if it exists, is difficult to remove. Those compounds reported in the literature to give reactions with thorium, and their related compounds were tested first. Then, other compounds having different but characteristic functional groups were examined. Several of the compounds tested were synthesized in this laboratory, and many were prepared specially by commercial firms and by the University of Maryland. These special compounds were ordered on the basis of the reactions of related compounds, and several of them were the most promising of the colorimetric reagents tested.

Ninety-three compounds were tested qualitatively. Those that gave a reaction were studied further. The optimum conditions for the reaction in regard to pH, reagent concentration, alcohol content, and the possibility of extraction were determined. Spectrophotometric curves and standard curves were prepared for the promising reagents. The range and sensitivity of the reactions were determined.

The types of compounds tested, the number of each type, and the number of reacting compounds are given in the following table.

Type of compound	Number tested	Number reacting
Flavonols	4	3
Anthraquinones	12	7
Monoazo	45	20
Disazo	18	3
Misc.	14	5
Total	93	38

The monazo compounds having 2 OH groups ortho to each end of the N = N group, and one or two NO_2 groups meta to one end of the N = N group, as in the compounds 1-hydroxy 2-nitrophenylazo 2-naphthol and 1-hydroxy 2,4-dinitrophenylazo 2-naphthol were the most promising colorimetric reagents. The latter compound seemed to be the better reagent, and its complex with thorium could be extracted with ether and with ethyl acetate. However, about 5 micrograms of ThO_2 in 25 ml of solution before extraction appeared to be the minimum that could be determined. This was not nearly the sensitivity we had desired. It was also no better, and perhaps less sensitive than 1-(o-arsonophenolazo) -2-napthol-3, -6-disulfonic acid, which is widely used.

Comparison on a mole basis with well known "sensitive" colorimetric reactions of other elements, indicates that 1-5 micrograms of thorium dioxide is about the minimum one would expect to be able to determine colorimetrically. Therefore, it was decided to concentrate on fluorimetric reactions, because in many instances they are more sensitive than colorimetric reactions.

Very few of the reagents tested showed any fluorescence. Of those that did, morin was by far the most sensitive, and was also the only one which showed greater sensitivity to thorium than to zirconium. Therefore, attention was concentrated on the reactions of morin and thorium. With morin 0.1 to 0.5 micrograms of ThO_2/25 ml of solution can be determined in the absence of other cations. A good standard curve can be prepared, but the same curve cannot always be prepared on consecutive days. This may result in part or entirely from the cemented sample cell which was the only kind we had. The reaction does not seem to be stoichiometric. So far the following facts are understood:

1. The effect of different acids, and their concentrations on the fluorescence. The optimum pH has been determined.

2. The effect of alcohol concentration on the fluorescence. There is an increase in fluorescence with increase in alcohol content. Therefore the alcohol content must be controlled.

3. The morin concentration must be controlled.

4. The temperature should not vary too much.

5. The absorption of the ultraviolet light (365mu) by morin follows Beer's law and seems independent of the presence or absence of thorium.

6. The wavelengths of ultraviolet light which produce the fluorescence are known.

7. The wave band of the fluorescent light has been determined.

8. The fluorescent light is not absorbed by the fluorescing solutions.

One of the most disturbing unanswered questions is whether or not a definite complex is formed. It would appear otherwise. Both a fluorescence and a color are developed when ThO_2 and morin react. The fluorescence may be observed in 0.4 N HCl; its intensity increases to a maximum in 0.02 N HCl and then decreases with further decreases in acidity. The color is evident first in 0.03 N HCl and steadily increases as the acidity decreases. No solutions less acid than 0.0005N were tested.

With a fixed amount of morin both color and fluorescence increase with increase in the amount of thorium. No measurements have been made on the color intensity, but fluorescence measurements with 100 micrograms of morin and varying amounts of thorium gave a straight line curve when the mole ratios of ThO_2/morin ranged from 1/112 to 1/1.6.

With a fixed amount of thorium (between 3 and 46 micrograms of ThO_2) the fluorescence increases with morin until 100 micrograms (25 ml total liquid volume) of morin are present; the fluorescence then decreases. The morin quenches the fluorescence by absorption of the exciting light; however this effect does not seem to account entirely for the quenching which occurs. In contrast to the behavior of the fluorescence, the color developed by a fixed amount of thorium continues to increase with increases in morin. It appears that some sort of association between the thorium and morin takes place, maybe a mass action effect that is dependent upon both the thorium and morin concentrations, or the total concentration of the two. So far there is no information on the effect of other ions.

The reaction between thorium and morin is very tricky and affected by many factors, several of which would appear to make it look impossible for quantitative use. On several occasions we discontinued work on morin but have returned to it because of its sensitivity, (10 to 30 times better than anything else tried so far), and the good standard curve obtained over a large range of thorium concentrations.

As part of this study a new transmission fluorimeter for solutions has been designed. This first cardboard instrument makes it possible to study fluorescence reactions in solutions in a way not available before. We can now use very thin (i.e., shallow) solutions, and different depths of solutions and thus eliminate many of the effects of quenching which result from absorption of the exciting light by the solution.

Work on this whole problem of thorium analysis will continue.

<u>The determination of micro amounts of P_2O_5 in the presence of As, Si, and Ge, by Harry Levine and F. S. Grimaldi</u>

Work on this project continued intermittently during the half year. The main goal has been to determine very accurately the phosphorus content of sea water. It is necessary in this study to take into account the arsenic, silicon, and germanium contents of the water as these elements are serious interferences in present methods. Most of the goals have been attained and the experimental work is almost completed. We have abandoned schemes which would allow the determination of phosphorus without separations as being impractical. Instead, a simple separation of the phosphorus has been devised and tested and proved excellent. The phosphorus in water is concentrated by coprecipitation on aluminum hydroxide. Arsenic, germanium, and silicon that may be carried down are removed by treating the precipitate with HF and HBr and volatilizing these elements. The phosphorus remaining is determined by the molybdenum blue procedure under optimum conditions previously established.

Phosphorus was determined on distilled water "spiked" with known amounts of phosphorus, and on several samples of Gulf Water, some being "spiked" with additional phosphorus. Recoveries in all instances were excellent.

We hope to prepare a report on this method shortly.

<u>A new model transmission fluorimeter for use in the fluorimetric method of analysis for uranium, by C. A. Kinser</u>

A new model transmission fluorimeter has been designed and built in an effort to produce a more sturdy and versatile instrument which will satisfy all the needs of laboratories doing both research and routine uranium analyses.

This fluorimeter uses the same photomultiplier-tube housing, sample slide, and filters as the Model V fluorimeter which was developed in this organization by Fletcher, May and Anderson (TEI-233).

High voltage for the plates of the photomultiplier tube is supplied by a high quality, rugged, and very well-regulated power supply which is available commercially. This unit is continuously variable from 500 to 3000 volts and voltage output is controlled within 0.01%.

Output from the photomultiplier tube is measured on a commercially available electronic ultra-sensitive D.C. microammeter which has six ranges from 0.01 micro-ampere full scale to 1 milli-ampere full scale.

The ultra-violet light source consists of the same small 3-watt lamp as was used in the battery powered fluorimeter developed by Fletcher and May. In the present fluorimeter, however, the batteries have been replaced by a very convenient line operated power-supply which is continuously variable from 0 to 24 volts, regulated by means of a voltage regulator and filtered to give practically no ripple.

The complete instrument has been under test and in use in this laboratory for several months and has proved to be very rugged, versatile, sensitive, and convenient. By its use uranium values varying by several thousand fold can be measured accurately and reproducible from a series of standard curves which are linear and parallel.

Compactness has been achieved by the use of the small ultra-violet lamp instead of the large lamp, lamp-housing and blower system. The entire unit is line operated with the exception of the D. C. micro-ammeter which was operated for almost one year before battery replacement was necessary. A report is being prepared on this fluorimeter.

Bibliographic work, by Frank Cuttitta

The status of the four annotated bibliographies (TEI-280, p-69) is as follows:

1. Annotated bibliography of the analytical chemistry of the rare earths:- Complete except for subject index.

2. Niobium and tantalum:- Completed

3. Zirconium - hafnium:- Completed

4. Thorium - Completed

Work on these bibliographies has been done as part of research on analytical methods for elements important to the Survey's program of investigation of radioactive materials. It is important to note that these bibliographies have not been prepared elsewhere and they are badly needed. They will be issued for wide distribution as time permits.

Zirconia dishes in fluorimetric uranium analysis, by Frank Cuttitta and F. S. Grimaldi

At present platinum containers are used for the preparation of the fluorescing melts in uranium analysis. When platinum is used as the container the temperature and time of heating during the preparation of the melt are critical. Various amounts of platinum are introduced in the melts which cause variable degrees of quenching. Accuracy in uranium analysis is therefore dependent primarily on rigid heating techniques. It would be of considerable advantage if some material (which does not quench uranium fluorescence) could be substituted for platinum. Preliminary work indicates that ZrO_2 is refractory enough to be unattacked by the flux used in preparation of the melts. Zirconium also does not quench uranium fluorescence.

We have already contacted various manufacturers for ZrO_2 dishes. We hope to try these out when we obtain them and if feasible substitute them for platinum.

Direct fluorimetric determination of uranium in zircons, by Frank Cuttitta

Problem.--We have found some difficulty in obtaining accurate results for uranium in materials containing zirconium by fluorimetric procedures using fluoride-carbonate fluxes. The dilution techniques or chemical separation techniques allow some zirconium to accompany uranium before the melt is prepared and it is difficult for the flux to dissolve the uranium from a matrix of ZrO_2 that may form on ignition prior to the addition of flux and preparation of the melt.

As part of the Geological Survey's project on the distribution of uranium in igneous rocks, we have been called upon to analyze very pure specimens of zircons. Because of the purity of the mineral separates and because zirconium is not a quencher we thought of investigating the possibility of using a direct method employing milligram amounts of sample and thus simplifying the determination of uranium (0.001 percent and above) in zircon. Since elements such as Si, Ti, Hf, Th are present in zircon, it is also necessary to determine what amounts of these elements can be tolerated before quenching becomes apparent.

Preliminary experiments indicate that most of the trouble mentioned under (1) can be eliminated by omitting the ignition of the evaporated uranium and zircon solution prior to the preparation of the fluoride-carbonate melt. Work on (2) is in progress.

Preparation of lead iodide for mass spectrograph isotopic study by electrolytic means, by Henry Mela, Jr.

As part of the Survey's program in isotope geology we have to isolate enough lead from carnotite and other materials for mass spectrographic determination. Many of the materials contain no more than 0.001 percent lead in the presence of large amounts of vanadium and other commonly occurring elements. This requires the processing of samples sometimes as large as 500 grams.

The present method for separation of lead and preparation of pure lead iodide is a tedious and time-consuming one, and there is a need to considerably shorten it, if possible.

The classic anodic separation of lead by electrolytic means offers the possibilities for elimination of lengthy chemical manipulations and for isolation of pure end-product. It should be possible to make an initial separation of lead and other Group II metals by precipitation of the sulfides, followed by acid solution, and electrolysis using platinum electrodes.

A study has been completed of the following:

1. Optimum conditions for the recovery of lead by electrolysis.

2. Electrolytic behavior of the individual metals of Group II and vanadium with lead.

3. Electrolytic behavior of a composite of Group II metals and vanadium with lead.

This work will continue.

<u>Investigation of methods for concentration and measurement of lead in sea water and marine deposits, by D. R. Norton</u>

The objective of this work is to isolate samples of lead from materials from marine environment for mass isotopic determination. To reach this objective we are investigating the concentration of lead in sea water and in marine deposits. Problems pertaining to methods of concentration and separation of lead are also being studied.

Our work on the chemical constitution of lead in sea water using radioactive isotopes indicates that most of the lead is associated with the suspended materials of sea water samples. At pH 8 a large fraction of the lead added to sea water can be removed by passage thru a fine sintered glass filter. Extraction of lead from sea water was affected by ion exchange media and by such adsorbents as sea sand and charcoal but the relative importance of filtration, ion exchange and adsorption has not been ascertained. In order to verify and extend these studies we are planning a series of experiments in co-operation with Woods Hole Oceanographic Institution.

Another phase of this project is a study of marine deposits which contain enough lead to warrant its separation. Lead has been detected in a manganese nodule and in a calcareous deposit, globigerina ooze. The work is being continued on samples of cores from the Bahamas Islands and from the Pacific. Other marine deposits are being acquired for the chemical and spectrographic determination of lead.

Radiometry
by Frank Senftle

The general problem of thorium analysis below 0.1% Th by radioactivity methods is still being pursued. Various methods and adaptions of the conventional thoron method have been tried but have not been satisfactory where the Th/U ratio is low. Moreover the added equipment to cool the water and air necessary for the equipment in the Washington area made the method impractical. For these reasons the above method has been abandoned and a photographic technique for thorium analysis is now being studied. Unlike most photographic techniques this method is not based on differences of alpha energies in the two series, but on the number of multiple track stars formed by certain members of the thorium series. Radium is precipitated from the rock solution. Radium 224 in the solution builds up in several days and multiple alpha tracks are formed from its short decay daughter products giving a direct measure of the thorium content of the solution.

The investigation of surface adsorption of different radioactive cations on mineral surfaces is being continued. It has been shown that the adsorption on crystal faces is neither uniform nor monomolecular and that this is one of the chief errors in the radioactive method of surface area measurement. In the case of quartz, adsorption is heaviest on the basal side of the pyramidal faces and decreases toward the apicies. Further, the tests made to date indicate that the different faces of giant quartz crystals have different adsorptive powers. Differential adsorption on twinned faces suggest a method of determining twinning in these crystals and it is planned to investigate this further.

In support of the geochronology program a theoretical investigation of the effect of isotopic diffusion has been undertaken. The general equation describing the approximate circumstances has been worked out and is now being applied to several cases. No results have been obtained at this time.

Calculations of the standard deviations for the difference between chemical and radiometric uranium analysis have been continued for samples of Florida phosphates. The standard deviation for this difference on 38,000 samples is ± 0.0022%. A "run" chart showing the standard deviation of each lot in the order in which it was analyzed has been prepared. An effort is being made to show some evidence of what type of sample is responsible for the large differences between the two methods which has been experienced for some sample types. A report on this work is now in preparation.

The emanation method of investigating crystal structure is being applied to zircon crystals. Considerable difficulty has been experienced in building an apparatus for heating the crystals and measuring the emanation at the same time. However, it is hoped that the difficulties have now been circumvented and that some results will soon be forthcoming. A study of the

the relation between radioactivity and metanicitization is planned.

Spectrography
by Claude Waring

Work continued by J. N. Stich during the last six months, in the effort to apply controlled atmosphere techniques to analytical problems. The possible elimination of molecular banding by controlling the atmosphere in the arc should make available all spectral lines for inspecting of the refractory elements, and also those possessing analytical lines in the cyanogen region of the spectrum, i.e., 3,800-4,250 A.

Thorium spectra were investigated, using the following atmospheses:

92% helium	-	8% oxygen
85% helium	-	15% oxygen
50% helium	-	50% oxygen
100% oxygen		
100% carbon dioxide		
50% carbon dioxide	-	50% helium

(Tests to be conducted with other gases)

Standard mixtures of ThO_2 in U_3O_8 and thorium standard electrodes prepared with solutions were used. The wave-length range from 2080 A to 10,000 A was explored with the Gaertner prism spectrograph. Tests were also made with the Baird grating instrument. In every case, the thorium line at 4019.137 A appeared to be the most sensitive one. The maximum sensitivity obtained was about 0.05% (on the basis of a 10-mg sample), using 100% CO_2. The CO_2 effectively eliminated the cyanogen bands. The introduction of helium into the arc chamber considerably suppressed the excitation of thorium and uranium. Higher amperages, i.e., 15-16 amps rather than 9-10 amps, did not increase sensitivity. The use of 100% oxygen caused too rapid burning of the electrodes.

Continued investigation of this problem and of the possible application of controlled atmospheres to analytical procedures would seem worth while, especially for samples containing high percentages of uranium and low thorium content.

J. N. Stich left the Survey during September. The controlled atmosphere tests will be continued by C. S. Annell.

TEI-274, (October 1952), "Spectrographic identification of mineral grains," by J. N. Stich was completed. The abstract follows:

"A qualitative spectrographic method of analysis of single mineral grains, impurity inclusions, X-ray powder spindles, and other small samples weighing 1 mg or less is described. Samples weighing as little as 0.01 mg have been analyzed. When 1 mg of sample is available, the accuracy of the method approaches that of a semiquantitative one. During a ten month period, 20,000 determinations of 69 metallic and metalloid elements in over 300 small samples have been made with the method. In conjunction with petrographic, physical, and X-ray methods, these determinations of chemical composition have been useful in establishing the mineral identity of small single grains. A direct current arc is used. The solution procedure of standardization involving only one element per plate greatly facilitates the selection of reliable analytical lines. A small carbon electrode cut from 1/8-in.-diameter graphite stock is used; this is convenient for the loading and arcing of X-ray powder spindles. The medium quartz prism spectrograph is preferable to a grating instrument for qualitative micro analysis as its complete spectrum coverage for a single exposure includes the most sensitive lines of the alkali elements."

The first phase of the automatic scanning project was completed, i.e., to determine if the Leeds and Northup microphotometer could be applied to automatic line interpretation. This phase was sucessful and a few samples were analyzed by the method. Although this instrument is not the ideal one for the job, it could be used. The second phase of the work will be to develop a more suitable instrument for the automatic scanning of plates. Also in connection with this project, the idea of eliminating the spectrographic plate, and using direct scanning is a possibility. C. Waring, H. Worthing, C. Annell and K. Valentine are working on this project.

The results of the cooperative project by the Chemistry and Spectrography Units on the effect of ashing temperature on the volatility of germanium in lignite samples are reported in TEI-267 by Wendell R. Tucker and Claude L. Waring (September 1952). The abstract follows:

"A study has been conducted to provide data on the loss of germanium from ashed lignite samples. The lignite samples, of known germanium content, were ashed at various temperatures as high as 1000°C with varying rates of heating and varying amounts of surface area of the lignites. The results indicate that no germanium was volatilized during the various ignitions."

The results of a cooperative project by the Mineralogy and Spectrography Units on the concentration of minor and trace elements in ash of low-rank coals are given in a report now in preparation, "Concentration of minor and trace elements in ash of low-rank coals from Texas, Colorado, North Dakota, and South Dakota", by M. Deul and C. S. Annell. The tentative abstract follows:

"As part of the routine geochemical investigations of coal, 282 lignite samples of seven areas were analyzed spectrochemically. C. L. Waring and C. S. Annell of the Geological Survey developed the method used for the semiquantitative estimation of 68 elements in one exposure of a 10-mg sample.

"B, Ba, Sr, Pb, Ti, P, and Mn are present in concentrations as high as 0.1 to 1.0 percent in most of the areas; As, V, Mo, Zr, Zn, Ni, Co, Be, and Y are present in similar concentrations in fewer areas. Cu, Cr, Sc, Ga, Ge, Li, and La are present in concentrations as high as 0.01 to 0.1 percent; Yb is present as high as 0.001 to 0.01 percent; and Ag was not found in concentrations higher than 0.001 percent.

"There are unusually high concentrations of Pb, Sn, Sr, Mo, Co, B, and La in many of the coal ashes analyzed. The trace element content is given for ashed lignite from each of the seven areas."

Research and development were confined to problems arising in the laboratory, with reference to the determination of various elements in different materials. Solution of some of these problems resulted in the development of the following methods:

(1) The quantitative determination of thorium in zircon. H. Worthing

(2) The determination of trace amounts of gold in bronze. C. S. Annell

(3) The quantitative determination of all elements below one percent in Oklahoma zircons. C. L. Waring

(4) The quantitative determination of vanadium in phosphate rock. C. L. Waring and K. Valentine

(5) The quantitative determination of lead in monazite and cyrtolite. C. L. Waring

(6) The quantitative determination of germanium in aluminum silicate materials. H. Worthing

(7) The completion of semiquantitative standard plates at 60 and 120 second exposures for the following elements: Te, Er, Ho, Ag, Fe, Ta, Zn, and Zr. This work is part of the change-over program to arc most all of the samples for 120 seconds, to insure complete burning. C. S. Annell

(8) The quantitative determination of Sr, Rb, and Pb in sea water, globigerina ooze, limestones and dolomites. C. L. Waring, H. Worthing

(9) The semiquantitative determination of the alloy constituents of inconel and stellite. H. Worthing

An evaluation was made of the quality of certain spectrographic analyses both in Washington and Denver by the staff of the Spectrography Unit, with the aid of the Chemistry Unit.

A lot of 99 Mexican phosphate samples were analyzed semiquantitatively in the Washington and Denver Laboratories. The samples analyzed in both laboratories were thought to be equivalent splits. The results of these comparisons were considered to be taken under normal working conditions. Differences in nickel and sodium content were noted in six of these samples. Chemical analysis for these elements showed that the Washington nickel determinations were high by one bracket in three cases and Denver was low by the same amount in two cases. The Washington laboratory was high by one bracket in the six sodium cases, and Denver was one bracket low in six cases. Inspection of the original spectrograms showed that most of these differences were border line cases in the sense that there was some doubt as to which of two adjacent brackets they belonged. This, however, is true of any procedure which involves assigning the results to one of a series of arbitarary categories.

Crude phosphoric acid samples were analyzed in both laboratories. Thirty four elements were found to be present, five of these showed disagreements in the magnitude of one bracket. The disagreements were probably due to the different methods of sampling the sludge containing phosphoric acid.

Five silicate rock samples were analyzed in both laboratories. Of the 210 determinations involved, 8 disagreements by one bracket were noted.

GEOCHEMICAL AND PETROLOGICAL RESEARCH ON BASIC PRINCIPLES

Distribution of uranium in igneous complexes

by Esper S. Larsen, Jr.

During the summer Prof. John B. Lyons of Dartmouth joined the project on a part time basis and is working on the three early granitic series of New England. Other work on the younger series of granites is also in process and the combination of these studies should enable us to compare granitic rocks of different ages, and possibly some formed by granitization. David Gottfried and George Phair spent about a month in the Front Range of Colorado. They collected granites, pegmatites , aplites, contact rocks, inclusions, and gruss. In one section the Boulder Creek batholith was sampled from contact to contact at $\frac{1}{2}$-mile intervals over a distance of 10 miles.

Their field tests indicated that the Silver Plume, which is the youngest of these granites, is much more radioactive than the other granites of this area. Gottfried also collected from the Tertiary intrusives of central Colorado.

We are cooperating with other members of the Survey and now have on hand or in the course of being collected groups of rocks from:

The Southern California batholith

The Sierra Nevadas, California

The Idaho batholith

The granites of the Front Ranges of Colorado

The lavas of the San Juan Mountains, Colorado

The lavas from Modoc County, northern California

The volcanic rocks of the Valles Mountains, New Mexico

The four magma series of New England

The potash-rich volcanic rocks of Montana

We have chemical uranium determinations on about 35 granitic rocks ranging from gabbro to granite, carefully selected to represent the batholith of Southern California. All rocks have been analyzed for the major constituents. Plotted on a variation diagram, the U determinations do not fall so near on a smooth curve as do the major constituents. On the curve the gabbros have a strong tendency to be low in uranium (about 0.2 ppm) and the granites to be high in uranium (5.0 ppm). The estimated average U content of the batholith is 2.5 ppm.

We have separated the minerals from a number of rocks from Idaho and Southern California. Monazite was known to be abundant in the Idaho batholith and we have found it to be nearly as abundant in the very siliceous rocks of the California batholith.

Xenotime was found in both batholiths. Both minerals are confined to the latest differentiates and monazite comes in somewhat earlier than the xenotime. Xenotime is confined to muscovite-garnet granites and it was found in every such granite tested. We are separating xenotime for analysis, as analyses of this mineral are few and the uranium content is reported as from 1 to 3 percent.

We have worked some on the use of zircon, xenotime, and monazite to determine the age of rocks and are reasonably confident that we can determine the age with a fair degree of accuracy. A paper on the method for determining the age of igneous rocks using the accessory minerals by Larsen, Keevil, and Harrison has been published (Geol. Soc. Am. Bull. 63).

Larsen, Waring, and Berman have nearly finished a paper on the zoned zircons from an Oklahoma pegmatite. These crystals have cores of fresh zircon with about 0.029 percent uranium and a main part that is metamict and has about 0.155 percent uranium. The ages derived from the two parts are the same (620 million years) as they should be.

William Smith with the cooperation of Prof. Bernard of the University of Wisconsin has been investigating the effects of decolorizing and irradiation of smoky quartz with liquid **inclusions**. At present they are awaiting temperature determinations. The smoky quartz is believed to be due to radioactive bombardment.

An investigation of the colorimetric determination of thorium in zircons and other allied mineral species was begun. Three methods of isolation and concentration of traces of thorium in the presence of macro-amounts of zirconium will be studied and thoroughly tested. Most of the studies will be directed toward the elimination of Zr and Ce interferences.

Work continued on the rapid and direct fluorimetric determination of uranium in zircons. Results obtained from many experiments indicate excellent correlation between the extraction method, which is now in use, and the short and rapid direct method proposed.

Weathering, transportation and redeposition of uranium

by Robert Garrels

Because this project has just been activated a restatement with aims and procedures should be made.

Although the richest deposits of uranium are in the vein deposits formed through igneous processes, the largest are formed as a result of secondary processes which release uranium from rocks and redistribute it. Such secondary deposits include all of the bedded sedimentary deposits, such as the uraniferous phosphorites and black shales. Also, weathering is an important process in the formation of deposits of the carnotite type. This last is one of the reasons that the initial emphasis of this investigation will be focused on the Colorado Plateau deposits.

Little is known about the behavior of uranium during weathering. Until the environmental factors that control its solution, transportation, and redeposition are known, no fundamental basis exists to guide a search for secondarily developed deposits.

The investigation proposed, therefore, has as its fundamental objectives the understanding of (1) the means and manner by which uranium is removed from various types of rocks, and (2) the deposition of uranium in weathering products--both minerals and solutions.

The approach to the study of the behavior of uranium during weathering will consist of three major steps:

(1) Theoretical and experimental determination of the solubility and stability of uranium and associated compounds as functions of pH, oxidation potential, and composition of the ground-water solutions.

(2) Comparison of synthesized materials with natural materials in terms of identity of compounds and type of mineral associations.

(3) Application of these relationships to specific uraniferous deposits (in collaboration with Mineral Deposits Branch).

The initial investigations will have special application to the

Colorado Plateau type of uranium occurrence. It is becoming apparent that there are two types of mineral associations on the Plateau. One contains lower valence uranium and vanadium compounds, as well as variety of sulfides. The other contains higher valence uranium and vanadium compounds, as well as a variety of sulfates. The implication is strong that the second is derived from the first by weathering.

Work has already begun on the study of theoretical relationships among the lower valence vanadium oxides. Experimental work on this system will be started in the near future.

Synthesis of uranium-bearing minerals
by Irving Friedman

Most of the uranium in igneous rocks is contained in zircon. As an aid in studying the fixation of uranium, an attempt is being made to synthesize zircon crystals containing uranium. It is hoped that a study of such materials will aid in our understanding of where the uranium is in the zircon lattice and also under what conditions of temperature, pressure and concentration this substitution takes place. George J. Jansen has made some preliminary runs in the system ZrO, SiO_2, Na_2O, H_2O at temperatures from 200 to 450 C. The solubility of zircon in sodium hydroxide solutions at these temperatures is low, about 5 mg/10 ml in 10% NaOH at 450 C. Work in this system will be continued when additional high pressure equipment is completed.

The uranium-vanadium minerals are important sources of uranium in the Colorado Plateau deposits. In addition to their value as ore minerals, they are also excellent indicators of the conditions of temperature, pressure, pH, oxidation potential and concentration at which the uranium was transported and fixed. A fundamental study of first the vanadium mineral systems and finally the uranium-vanadium systems has begun.

Richard Marvin has completed the first phase of a study of the system V_2O_5, K_2O, H_2O at 20 to 95 C. The stability fields of 4 solid phases, two KVO_3, V_2O_5 and unknown hydrous phase have been delineated as a function of pH, composition and temperature. We plan to extend this research shortly to the system CaO, V_2O_5, K_2O, H_2O. This larger system contains the minerals hewettite, metahewettite, rossite, metarossite and pascoite.

Isotope geology

Isotope geology of the Colorado Plateau ores
by Lorin Stieff and Thomas Stern

Laboratory investigations.--A paper entitled, "The lead-uranium ages of some uraninites from Triassic and Jurassic sediments of the Colorado Plateau," by L. Stieff and T. Stern was presented at the November meeting of the Geological Society of America. The abstract of this paper was given in the Quarterly Progress Report for the period April 1 - June 30, 1952 (TEI-280). A detailed report of the G.S.A. paper is given below.

The study of the origin of the uranium deposits in the Triassic and Jurassic sediments of the Colorado Plateau by means of age determinations on the uranium ores they contain is nearing completion. Approximately 85 age determinations by the lead-uranium method have been made from many types of Plateau ores from all of the mineralized stratigraphic units. Approximately 30 samples of uranium ore and galena have been prepared during the last six months and are now awaiting analyses. Twenty to thirty carefully selected, additional samples should complete this part of the study of the origin of the Plateau deposits.

The immediate objective of this age study has been to establish, within very broad limits, the time at which the present Colorado Plateau uranium deposits were formed. No attempt has been made to set more precise ages for the uranium ores because many of the ore specimens have been altered by the relatively recent action of ground waters. Geologic field and laboratory evidence, combined with these data on the age of the uranium ores, has partly answered and may be expected to fully answer the following questions:

1. Were the uranium deposits of the Colorado Plateau formed shortly after the deposition of the enclosing late Triassic and late Jurassic sedimentary rocks, or were these deposits formed at some more recent time, perhaps at the end of the Cretaceous or the beginning of the Tertiary?

2. Was the uranium in the Plateau deposits precipitated from streams during Jurassic and Triassic times or did the ore solutions come from depth?

3. Were the uranium deposits localized only by sedimentary structures and carbonaceous material or have the major structural features in the Plateau also played a part?

If the deposits were formed shortly after the enclosing sediments were laid down, then the youngest ages that could be assigned to these sediments would be the age at which the Triassic and Jurassic periods, themselves, are thought to have ended. On the bases of several different methods, Professor Arthur Holmes of Scotland has estimated that the Triassic period ended 152 million years ago, the Jurassic period ended 127 million years ago, and the Cretaceous period ended 58 million years ago.

Of these three ages, only the age of the end of the Cretaceous has been determined from specimens of uraninite by use of the lead-uranium method. The age of the end of the Cretaceous is thought to be the most reliable because uraninites are considered to be among the best materials available for geologic age determinations. The ages for the end of the Triassic and Jurassic periods have not been estimated by as satisfactory methods and may be assumed to be only approximately correct.

All specimens of Plateau ore are not equally satisfactory for age determinations. Alteration of the ore by ground water frequently results in a selective loss of uranium. The resulting Pb^{206}/U^{238} ages of the altered ores are, therefore, higher than the actual age of the specimen. Also, different types of uranium ore which are in the same geologic environment with respect to ground water alteration will lose uranium at different rates depending on the state of oxidation of the uranium in the uranium mineral. If, however, it is assumed that all types of Plateau ore samples are equally satisfactory for the purposes of age determinations and that none of the calculated ages can be excluded on the basis of independent geologic evidence, the mean Pb^{206}/U^{238} age of all of the Plateau ores is approximately 100 million years. Even this mean age of 100 million years is considerably less than either of the estimated ages of the Jurassic or the Triassic periods. This mean age includes seven samples whose ages are known to be impossibly high. These high ages can only be interpreted as a result of the selective loss of uranium due to leaching by ground waters. If these samples with impossible high ages are removed from the average the mean age drops to 85 million years.

Included with the remaining 78 samples of Colorado Plateau uranium ores are 21 specimens of uraninite and the new uranium arseno-silicate mineral, "coffinite" (see TEI-280, p. 85). Both uraninite and coffinite are associated with pyrite and other sulfides and the yellow secondary minerals such as carnotite and tyuyamunite are usually notable by their absence. When these secondary minerals do occur with either coffinite or uraninite they usually vein these latter minerals or surround them as **alteration halos**. In general, both coffinite and uraninite minerals contain significant amounts of UO_2 and as a result are less soluble in ground water solutions than is either carnotite or tyuyamunite which contain uranium as UO_3. Finally, both coffinite and uraninite are usually found either at depth or in areas which have been fairly well protected from oxidation and alteration by ground waters. Because the Plateau specimens of uraninite and coffinite appear to be primary uranium ore minerals and because they show less evidence of alteration than do the carnotite ores, the ages of these ores have been selected as being the most reliable.

The Pb^{206}/U^{238} ages of the uraninite samples from the Shinarump conglomerate of late Triassic age are given in table 10. These ages may be contrasted with Holmes' age for the end of the Triassic.

Table 10 .----Pb^{206}/U^{238} ages of primary uranium mineral samples from the Shinarump conglomerate of the Colorado Plateau

Location	Number of samples	Mineral	Mean age in million years
Happy Jack Mine	2	Uraninite	55
Cato Sells Mine	1	Uraninite	60
Lucky Strike Mine	1	Uraninite	65
Shinarump No. 1 Mine	1	Uraninite	75
Camp Bird Mine	2	Uraninite	80
Monument No. 2 Mine	3	Uraninite	85
	Mean age of 10 samples		72.5
Holmes' age for the end of the Triassic			152

It should be noted that the best material which has been used for age determinations from the Colorado Plateau uranium deposits was collected from the Happy Jack Mine in White Canyon, Utah. The ages obtained on these specimens are lower than the ages which have been found for any of the other uraninites from the Shinarump. It is believed that the Happy Jack specimens are essentially unaltered. The higher ages for the remaining uraninites are thought to be a result of the selective loss of uranium due to percolating ground waters.

The Pb^{206}/U^{238} ages of the minerals from the Morrison formation is shown in table 11 . The ages of these ores may be constrasted with Holmes' age for the end of the Jurassic.

Table 11.----Pb^{206}/U^{238} ages of primary uranium mineral samples from the Morrison formation of the Colorado Plateau

Location	Number of samples	Mineral	Mean age in million years
Grey Dawn Mine	1	Uraninite	65
Corvusite Mine	1	Coffinite, Uraninite	70
Matchless Mine	1	Coffinite	80
La Sal No. 2 Mine	5	Coffinite	85
Arrowhead Mine	1	Coffinite	90
Black Mama	1	Coffinite	90
		Mean age of 10 samples	82
		Holmes' age for the end of the Jurassic	127

Again, the best material which we have obtained from the Morrison formation gives the youngest age. The higher ages of the remaining samples is believed to be due to the selective loss of uranium.

The Pb^{206}/U^{238} age of uraninite specimens from the Colorado Front Range is given in table 12.

Table 12.----Pb^{206}/U^{238} ages of uraninite specimens from the Colorado Front Range

Location	Mean age in million years
Wood Mine (Nier-Holmes)	57.3
Wood Mine (Phair)	60
Gilpin County (Nier-Holmes)	59.8
Iron Mine (Phair)	70
Copper King (Phair)	55
Copper King (Phair)	68
Mean age of 6 samples	61.7
Holmes' age for end of Cretaceous	58

Two of these samples, Wood Mine (Nier-Holmes) and Gilpin County (Nier-Holmes), were used by Arthur Holmes to establish the end of the age of the Cretaceous. The remaining specimens of uraninite were collected by

George Phair of the Trace Elements Section and were analyzed in this laboratory.

Table 13.----Pb^{206}/U^{238} ages of uranium mineral specimens from the Colorado Plateau and the Colorado Front Range

Deposit	Number of samples	Mean age in million years
Morrison formation, Colorado Plateau	10	82
Shinarump conglomerate, Colorado Plateau	10	72.5
Placerville (vein)	1	65
Colorado Front Range	6	61.7

Table 13 tabulates the mean Pb^{206}/U^{238} ages of the uranium mineral specimens from the Colorado Plateau and the Colorado Front Range. In addition to the ages of specimens from the Morrison formation and the Shinarump conglomerate, the age of a specimen of uraninite and carbonaceous material similar to some of the Temple Mountain ores from a vein deposit in the Placerville area, has also been included. This specimen gave an age of approximately 65 million years.

To summarize, we believe four significant facts have been shown about the Colorado Plateau uranium deposits:

1. The ages of the best specimens of ore from the Morrison and Shinarump conglomerates are appreciably less than the ages of the sediments which enclosed them.

2. The ages which have been found for these ores from the Morrison formation and the Shinarump conglomerate are essentially the same. This strongly suggests that the deposits were actually formed at the same time regardless of the age of the enclosing sediments. More important, this means that the origin of the Colorado Plateau ores cannot be successfully determined if the

problem is subdivided into the problem of origin of the Morrison ores, the origin of the Shinarump ores, etc.

3. The age of the uranium ore in the <u>vein deposits</u> in Placerville area which are quite similar in many respects to the ores in the Temple Mountain district, is also approximately the same as the age of the Shinarump and Morrison ores. A similar source for the ore solutions is strongly implied.

4. The age of the uraninites from the Colorado Front Range is essentially the same as the age which has been found for the Morrison and Shinarump deposits. This would suggest a single period of mineralization for both the Colorado Front Range and the Colorado Plateau.

In the light of these data on the age of the uranium ores, two interpretations on the origin and the history of the Colorado Plateau uranium deposits can be made:

1. Uranium was deposited either at the same time or shortly after the enclosing Jurassic and Triassic sediments in which it is found were laid down, or the uranium was deposited in one of the overlying Cretaceous sediments. At the close of the Cretaceous or at the beginning of the Tertiary, the uranium and radiogenic lead which has been formed were taken into solution and the uranium was eventually redeposited in approximately its present sites. The deficiency of radiogenic lead for a syngenetic ore indicates that most of the radiogenic lead formed prior to the end of the Cretaceous could not have been redeposited in or near the ore.

The common lead, however, which was originally deposited in the sediments with the uranium was redeposited in the present sites. The selective removal of the radiogenic Pb^{206} and Pb^{207} lead isotopes from the solution poses an extremely difficult problem, the solution of which is not immediately apparent. During the period of dissection and erosion, the deposits were probably altered, partly leached, and partly redistributed by circulating ground waters.

2. A much simpler and more probable interpretation of the lead isotope data is that at the close of the Cretaceous or the beginning of the Tertiary uranium, common lead, a little old radiogenic lead, vanadium, and other metals were introduced into the sediments of the Colorado Plateau. These metals probably had similar sources or perhaps a common source to be found at depth. The original uranium and vanadium ore minerals were probably oxides or mixtures of oxides and silicates. During the period of dissection and erosion, the deposits were partly altered, partly leached, and partly redistributed by circulating ground waters.

The immediate objective of this age study of the Colorado Plateau uranium deposits has been achieved. The age of the best ore specimens is much closer to the age assigned to the end of the Cretaceous than it is to either of the ages of the Jurassic or the end of the Triassic. Our data strongly suggest that the source of the ore forming solution will be found at depth. Regardless, however, of the source of the ore solutions, it would seem certain that conditions prevailing during the close of the Cretaceous or the beginning of the Tertiary must have played an important part in localizing the deposit in their present sites.

From these conclusions, it would appear that the search for new deposits must rest in part on a thorough understanding of the late Cretaceous and early Tertiary history of the sediments of the Colorado Plateau. If the ore solution were introduced from below, it is possible that the potentialities of the Colorado Plateau as a uraniferous province have just been touched.

Field work.--During July, August, and the early part of September Tom Stern and Len Riley collected a number of specimens for age determination work. They were joined by Ed Erickson in August. Uraninites were collected from 11 new localities on the Colorado Plateau. Two of these new localities were from the Morrison. Three new localities were found for coffinite and one of these localities was in the Shinarump conglomerate. The Shinarump occurrence is the first which we have found for coffinite.

Isotope geology of lead
by R. S. Cannon, Jr.

The geologists on this project, R. S. Cannon, Jr. and G. J. Neuerburg, have been working on various phases of sample procurement. The projected study of variations in the isotopic composition of lead in diverse geologic environments throughout geologic time requires a wide variety of geologic materials carefully chosen for laboratory investigation. Basis for wise selection of sample materials for various phases of the investigation has been sought by extensive library research, conferences with colleagues, and consultation or correspondence with numerous geologists whose special knowledge is pertinent to our problems.

Recent attention has been concentrated on selection of materials specifically for the program of cooperative research on the isotope geology of lead and related problems that is planned with Professor Harrison Brown and associates in the geochemical laboratories being constructed at California Institute of Technology. For the most part these materials are rocks that contain only ordinary concentrations of lead and uranium: granites, volcanic rocks, marine sedimentary rocks, and so forth. General specifications worked out with the CIT group for field collection of these sample materials include special precautions to protect samples from hazard of contamination by extraneous Pb or U. To insure ample material for varied investigations, unusually large samples are being collected: about 200 pounds for granitoid rocks, 20 pounds for volcanics or limestones.

During the field season of 1952 many hundred samples bulking several tons were collected in the field and shipped to the laboratories in Pasadena and in Washington, D. C. Samples collected in western states by Neuerburg in the northwest or by Cannon in the southwest include collections of volcanic rocks from California (Clear Lake, Lessen, Hat Creek, Medicine Lake Highlands, Modoc Lava Beds, and Ludlow), from Oregon (Crater Lake, Newberry Crater), Idaho (Craters of the Moon, Shoshone), Wyoming (Yellowstone), Arizona (San Francisco Peaks, Roosevelt Dam, San Carlos), and New Mexico (McCartys, Valle Grande); limestones or dolomites of pre-Cambrian age from Arizona (Bass, Mescal), and from the Belt series of Montana (Altyn, Siyeh, Missoula, Grayson); younger limestones from South Dakota (Minnekahta), Colorado (Hermosa, Pony Express), New Mexico (Todilto), Arizona (Redwall, Bright Angel), and Utah (Moenkopi); batholithic igneous rocks from Montana (Boulder batholith) and Washington (Kaniksu batholith); and lead-bearing sulfides from localities in Montana, Idaho, Washington, New Mexico, Arizona, and Utah. It is a pleasure to acknowledge the numerous valuable additional samples that have been collected and contributed by many other Survey geologists not formally affiliated with this project: pre-Cambrian igneous rocks, limestones and dolomites collected by A. E. J. Engel from the Grenville Province (New York and Ontario); granites from southeastern U. S. (Georgia, North Carolina) by J. B. Mertie, Jr.; lavas from Paricutin volcano (Mexico) by Carl Fries, Jr.; volcanics from the islands southwest from Tokyo Bay (Japan) by Helen Foster; pumice from the Valley of Ten Thousand Smokes (Alaska) by R. E. Wilcox; and from the Pacific region volcanic rocks (Hawaii, Guam) and sea water (Eniwetok) by Earl Ingerson.

Systematic petrographic and chemical study of all these samples is being started. A large number of thin and polished sections have been prepared, a few have already been examined, and intensive microscopic studies are just getting under way. In the Trace Elements Washington Laboratory spectrographic examination will include semiquantitative scanning as well as quantitative determination of Pb. To date 27 volcanic rocks and 9 limestone-dolomite samples have been so examined, and on the latter, determinations of Sr and Rb have been made in addition. Uranium content of all samples is to be determined fluorimetrically, and Mg and Ca content of limestone-dolomite samples will be determined by chemical analysis. These tests will yield fundamental geochemical information while providing the data needed to show which samples in each category are worthy of analysis by isotope dilution techniques in the CIT laboratory. Additional chemical work that has been accomplished in the Survey Washington laboratory is the preparation of lead iodide for isotope analysis from 17 carefully hand-picked samples of galena, and analysis for Pb and U on 5 samples of galena concentrates for which isotope analyses are already available. During the next 6 months all of these laboratory activities will be stepped up, as well as the integration and reporting of results.

Instrumentation
by Irving Friedman and Lorin Stieff

In July work was resumed on the dual, 6" mass spectrometer by Lorin Stieff, David Lee, and Harry Allen. A well resolved beam was first detected on this mass spectrometer on September 20. Certain components of the mass spectrometer are now being redesigned and the spectrometer will be in full operation in the early part of 1953.

Irving Friedman is now building a 6" - 60° permanent magnet mass spectrometer. This spectrometer is designed for the analysis of gaseous specimens, particularly in the light mass range. This instrument is to be used for the analysis of the hydrogen deuterium ratio in samples of atmospheric hydrogen. We intend to extend the hydrogen-deuterium determinations to a variety of natural substances. We also plan research on oxygen in silicates and oxides using this spectrometer.

The construction of a third 60° mass spectrometer of 12" radius has been started for high resolution work in the high mass region. We do not plan to push construction of this machine until testing and revision of the first two spectrometers is complete.

In October Tom Stern and Lorin Stieff spent almost a week in Oak Ridge, observing in some detail the operation of the mass spectrometers. As a result of this trip and the information gained at Oak Ridge it seems certain now that part (and perhaps a large part) of the **anomaly** in the Pb^{207}/Pb^{206} ages is due to small systematic mass spectrographic errors. The Oak Ridge instruments apparently cannot completely resolve the smaller Pb^{207} peaks from the much larger Pb^{206} peaks. Arrangements are now being made to have similar samples analyzed at Argonne National Laboratory.

Age determination by the zircon-X-ray method
by F. E. Senftle

In connection with the general zircon-X-ray method being studied by the Survey (TEI-280), P. M. Hurley of Massachusetts Institute of Technology (working part-time) has made a number of determinations to aid this work. Seventeen zircon samples from western U. S. have been measured for thick source alpha emission and where feasible a helium determination was made. The helium ages ranged from 7 to 77 million years. The X-ray diffraction angle 2θ from the (112) plane was also measured for these specimens. The results showed a definite progression in relation to the age results and indicate a method of age determination if the X-ray curve can be properly calibrated.

Further work is planned to test this method, and also to use these results to cross-check the radioactive method applied to zircon. The first emphasis is to establish a small number of zircon samples which can be used as standards.

Radon and helium studies
by Henry Faul, G. B. Gott and G. E. Manger

The objectives of this investigation are briefly to determine the distribution and origin of the radon, helium, and their parent radioactive elements in the part of the Panhandle gas field known as the West Panhandle field and located principally in Moore and Potter Counties, Texas. The problems dealing with these objectives have been further investigated during the period covered by this report. The investigation included additional radon measurements, radium analyses of the brines associated with petroleum along the margins of the gas field, stratigraphic and structural studies of the gas-producing formations, a study of the distribution of some of the uraniferous asphalts, and quantitative and qualitative analyses of this material. Radon measurements have been made also on gas samples from the San Juan basin, and the Hugoton gas field. New data that have resulted from these investigations are summarized below.

The field operations of the radon survey, which had been resumed on June 16, 1952, were continued through the first quarter of fiscal 1953 until September 9th. The details of operation were quite similar to those of the previous summer. Gas from about 700 different wells was sampled and over 900 individual analyses were made. Results of the sampling program were plotted whenever possible, and a card index of wells and results was initiated.

Throughout the period of this report, samples and cuttings were collected both by the personnel of the Survey and by the various operators in the field. The cooperation of the oil and gas companies involved has been excellent.

Results of investigations

West Panhandle field.--The major effort of the radon survey party was directed toward completing the intensive gas sampling program of the West Panhandle field, started in 1950. About 570 different wells of the field were sampled and analyzed. Although the field was not exhausted of unsampled wells, it is believed that the general survey of the occurrence of radon in this field is essentially complete.

In addition to the routine analyses, special tests were conducted. Four dynamic tests were completed, two of them repeats on similar tests made during the summer of 1951. In the two repeats the results were very similar to those previously obtained, indicating that the dynamic characteristics of radon flow in the formation surrounding the gas wells are probably constant with time. Six cable tool holes in the southeast part of the field (Colorado Interstate leases) were followed down, with gas samples being taken as the hole progressed. In one of these (Masterson B36) the radon content reached the record value for this field, about 750 micro-microcuries/liter. (All radon concentrations are given in terms of micro-microcuries/liter at standard conditions (0° C. and 76 cm. Hg). However, the gas production was not sufficient, and the hole was abandoned. The results from the other five holes were disappointing, largely because all these holes were drilled in a region where the brown dolomite was very thin or absent. Another hole is now being drilled on the Thompson Ranch by the Kerr-McGee Oil Co., and it is intended to follow it down to completion.

San Juan basin.--The gases from three producing zones in the San Juan basin area, San Juan County, N. Mex., were investigated for radon content in order to obtain evidence as to whether radon might be associated with particular stratigraphic horizons.

In cooperation with the U. S. Bureau of Mines, gas samples of high (about $7\frac{1}{2}$ percent) helium content were collected at the Bureau of Mines Navajo No. 1 Well near Shiprock, San Juan County, N. Mex. All fourteen of the samples, taken under carefully-controlled test conditions, showed no measurable activity in gas that was issuing from the (Devonian) Ouray formation at depths of 6970 to 7000 feet below the surface.

During the fourth quarter of fiscal year 1952, an investigation of the Continental Oil Company's Table Mesa No. 17 Well, about 15 miles southeast of the Navajo No. 1, found radon content of about five micromicrocuries/liter from the gas produced from the (Mississippian) Madison limestone at a depth of 7450 to 7535 feet below the surface.

Composite samples of gas from the shallower wells of the San Juan basin, with production from the Upper Pennsylvanian or Permian, were gathered from the inlet lines to a compressor station of the El Paso Natural Gas Co. Activities of about 25 micromicrocuries/liter, approaching those of the West Panhandle field, were recorded for the samples.

Hugoton Gas field.--In order to determine the geographical extent to which high radon anomalies may be found in helium-bearing natural gases, the large Hugoton field, adjacent on the north to the West Panhandle field and lying in Sherman County, Texas, Texas County, Okla., and Stevens, Morton, Seward, Grant, Stanton, Haskell, Kearny, and Finney Counties of

Kansas, was investigated. About 120 wells were sampled according to a distribution that would give a fair cross-section of the field.

The gas from the shallower wells, produced from Permian formations at an average depth of 2700 feet, contained from 10 to 198 micromicrocuries of radon per liter. A few deep wells, producing from the basal Pennsylvanian at about 6050 feet, gave radon analyses of from 11 to 16 micromicrocuries per liter, averaging about 25 percent of the concentration of radon in the shallow wells. No systematic decrease in radon concentration was observed toward the north and east.

Bottom hole brines.--Radium analyses of 12 brines associated with crude oil around the margins of the gas field show that the brines contain rather high concentrations of radium. These analyses are as follows:

Name of well	Radium content (g/liter x 10^{-12})
Shamrock-Robertson B-3	126
Shamrock-Robertson D-2	140
Shamrock Hight No. 4	120
Berneta No. 1	724 (sample from Separator tank)
Berneta No. 1	950 (sample from well-head)
Berneta No. 4	1200 (drill stem test)
Dugan No. 3	450
Trigg No. 2	130
Hazel No. 2	650
Yake No. 7	34
Childers No. 2	610
Wittenburg B-2	680
Wittenburg C-2	830

Residual hydrocarbons.--Qualitative chemical tests indicate that trace amounts of uranium are found in some of the heavy residual oil that stains the dolomite and arkosic rocks near the radon-bearing, gas-producing zones. A few rounded, botryoidal, uraniferous (about 0.1 percent equivalent uranium) asphalt pellets have been found in the gas-producing formations.

These pellets are similar to the uraniferous (0.1 -1.5 percent uranium) asphalt pellets previously reported in the "Big Lime" formation above the gas-producing zones. The uraniferous asphalts do not appear to be concentrated enough to serve as a source material for the widespread radium and radon in the brines and natural gas.

Of possible signficance is the uranium content of the ash from a crude oil collected on the northeast side of the Panhandle field. The uranium content of the ash was 0.04 percent, and the ash content of the oil was 0.084 percent.

Structure maps.--Construction of isopach and structure maps of the radon-bearing part of the Panhandle field has been started. Although the preliminary data obtained from these maps suggest that this is a promising line of approach, the work has not progressed to the point where an evaluation can be made.

Conclusions and plans

Origin of the radon.--Tests of radon content versus cumulative production after long shut-down of wells show that near-equilibrium radon concentrations are achieved soon after the radioactivity-dead gas that is stored in the well during shut-down is produced. Although radium-bearing bottom-water brines have not yet been obtained from radon-producing wells, the appreciable radium content of the analyzed brines indicates that the interstitial water in the overlying gas-producing zones may contain sufficient radium to account for the measured radon concentrations. This supposition is considerably strengthened by analyses of spent acid residues. In the one well for which such data are available, there is a strong indication that both the radium and uranium are concentrated either in the interstitial water or on the pore walls of the rock, but are relatively unconcentrated in the rock matrix. Also, analysis of the dolomite cuttings from other wells above, below and between the gas-producing zones show only the low uranium content usually associated with dolomite; in these cuttings the porosity has been destroyed and the interstitial water washed away during the drilling.

As yet no quantitative estimate has been made of the radium content in the dolomite pores, but calculations will be made based on flow equations for the hydrocarbon gas and radon and on quantitative estimates of porosity, permeability and interstitial water saturation. If possible, the adequacy of radium-bearing interstitial water as a source of radon will be tested by sweeping hydrocarbon gases through radium-bearing brines contained in artifically prepared dolomite cores. Also an attempt will be made to relate the calculated radium concentrations in the interstitial water to measured radium concentrations in bottom-water brines. No analyses or tests have yet given a positive indication of the mode of occurrence or location of the ultimate uranium source of the radium.

<u>Sampling program</u>.--The nearly complete radon survey in the West Panhandle gas field has shown that the geological features which control the radon content of the gas are probably of the order of magnitude of the separation between the wells. It is believed that not much additional information would be gained from complete sampling of gas fields. Future radon sampling work, therefore, will concentrate on radon measurements on gases from various fields in the country and from as many different formations as

possible. It is quite possible that the high radon content is limited to the Texas Panhandle, and the adjacent Hugoton fields.

Radon-helium correlation.--Comparison of concentrations of radon and helium in different gas pay zones of the same wells, and comparison of radon and helium concentrations in different wells have failed to show any correlation between the two gases.

Geologic studies.--Examination of cuttings and logging of holes in the Panhandle gas field will continue as long as drilling activity in the field continues. Preliminary efforts are being made to arrange for measurements of geothermal gradient in this area in cooperation with Harvard University. The success of these measurements depends largely on our ability to find open dry holes that approach thermo-equilibrium.

The association of uranium and other metals with crude oils, asphalts, and petroliferous rocks

by R. A. Erickson, A. T. Myers, and C. A. Horr

Because of the apparent universal association of uranium with carbonaceous materials, investigations were started in fiscal year 1953 to determine the relationship of uranium and other metals with crude oils, natural asphalts, and petroleum extracts from petroliferous rocks. Other types of carbonaceous material such as black shales and coal or carbonized plant remains were not included in this investigation. Commission support for this project was withdrawn early in 1952 because of lack of funds, but due to the project's importance in a balanced program of geologic research on uranium, the Survey undertook its support.

Although crude oils, natural asphalts, and petroliferous rocks are known to contain appreciable amounts of radioactivity, little is known about the actual uranium content and the chemical nature of the uranium compound in these materials. Because the association of uranium with these natural hydrocarbons might have a bearing on the genesis of some types of uranium deposits, and because a knowledge of the nature of this association might aid in the search for new uranium deposits, the early objectives in this study were to investigate the uranium content and the chemical nature of the uranium-bearing compound in this type of organic material by chemical and spectrographic analyses of several types of crude oils and natural asphalts.

The ash of 29 crude oils, 22 natural asphalts, and 27 oils extracted from petroliferous rocks were analyzed chemically and spectrographically. The results of these analyses indicate that these natural hydrocarbons contain surprisingly large amounts of a rather constant suite of metals, including As, Co, Cr, Cu, Mn, Mo, Ni, Pb, V, and Zn together with significant amounts of uranium. These metals are the same metals that are common in the uranium deposits of the Colorado Plateau. The uranium content of the ash of the 78 samples ranged from less than 0.001 percent to 0.83 percent; the uranium content of the total oil or asphalt ranged from less than 1 part per billion to 1,137,000 parts per billion.

More than 0.01 percent uranium was found in the ash of ten of 22 natural asphalts, 11 of 27 oils extracted from petroliferous rocks, and one crude oil of 29. Some of the samples contained surprisingly large amounts of uranium. The ash of a petroleum coke from the refinery at Casper, Wyoming, contains 0.19 percent uranium; ash of elaterite from Duschene

County, Utah, contains 0.20 percent uranium; ash of gilsonite from Uintah County, Utah, contains between 0.05 and 0.5 percent uranium. The ash of two samples of heavy oil from the Dakota formation, one sample from the oil seep at Red Rocks Theatre, near Golden, Colo., and two samples from an oil seep in Golden Gate Canyon, just west of Denver, Colorado, contain from 0.096 to 0.48 percent uranium. The ash of asphaltite extracted from the Westwater sandstone member of the Morrison formation at Poison Canyon north of Grants, N. Mex., contains 5 percent uranium. An unashed oil extract from the Spergen limestone near St. Genevieve, Missouri contains between 0.01 and 0.1 percent uranium. Eight samples of semi-viscous asphalt and petroliferous rocks from the Moenkopi, Shinarump, and Wingate formations in the San Rafael Swell, Emery County, Utah, contain from 0.002 to 0.83 percent uranium in the ash. Four of these samples contain more than 0.1 percent uranium. The analyses of these samples and a more detailed discussion of this investigation is given in TEM-513, now in preparation.

Although the preliminary results of this investigation have uncovered more problems than they have solved, it has been established that uranium and certain other metals are consistently present, sometimes in unusually high concentration in natural asphalts, crude oils, and petroliferous rocks. It seems probable that these metals occur as metallo-organic compounds and are concentrated in the heavier, more asphaltic portion of petroleum. The high concentration of unusual elements in the ash of these natural hydrocarbons suggests that these elements were not included in the petroleum from the strata from which the oil is obtained but were concentrated by some agency connected with the actual formation of oil. It seems probable that organisms such as marine algae, crustaceans, molluscs, etc., were the concentrating medium for these metals, and as these animals died they formed the metal-rich marine muds which are possible source beds for petroleum. These metals might then become incorporated with petroleum in the form of metallo-organic compounds. If this relationship of the metals to the petroleum source bed is real, it opens up new avenues of approach to the search for uranium deposits.

MINERALOGIC AND PETROGRAPHIC SERVICE AND RESEARCH

Service
by Theodore Botinelly

During the period from June 1 to November 30, 278 samples were received by the public sample program. Letter reports and acknowledgments were sent in response.

Identification

A total of about 175 samples were received, mainly from Survey personnel engaged in Trace Elements work, and were identified mineralogically.

Weight percents of minerals were made by grain counts on 1,245 samples from the Southeastern Monazite Exploration project.

X-ray

Approximately 575 powder patterns were run on laboratory project samples, samples from Survey field personnel and on samples received from the A. E. C. A total of 326 X-ray spectrometer patterns were made, chiefly on samples from the laboratory. About 300 powder patterns at Harvard and at the Trace Elements Washington Laboratory were measured to prepare data cards on d spacings for both the Washington and Denver laboratories.

Electron Microscopy

A total of 525 micrographs on 66 samples were made. The samples came chiefly from various laboratory projects.

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Research

Properties of uranium-bearing minerals
by John C. Rabbitt

Work progressed slowly during the past six months on the monograph "Mineralogy of Uranium", under the editorship of Rabbitt. Clifford Frondel of Harvard University, who has a W.A.E. appointment with the Geological Survey is writing the chapter on description of properties; Judith Frondel is preparing descriptive tables; George Switzer of the National Museum is writing chapters on the occurrence and association and the geographic location of the minerals; Theodore Botinelly is writing a chapter on characteristic methods of identifying uranium minerals in the field and laboratory. The total writing part of this job is about one-half finished.

During this period analytical work was completed by Frank Cuttitta on pure samples of becquerelite, schoepite (2 samples), synthetic zippeite, mineral "X", and renardite. The analytical work consists of complete chemical analyses and for most samples only from 10-50 mg are available for analysis. The results of this analytical work will be included in the monograph.

Judith Frondel is investigating the hydrous uranium oxides and she presented a paper, "Billietite and Becquerelite" (TEI-280, pp. 91-92) at the annual meeting of the Geological Society of America in Boston in November. She is now preparing a paper on vandendriesscheite, masuryite, and mineral "X" (TEI-280, p. 91).

The results of X-ray and thermal studies by Clifford Frondel on thorogummite (including nicolayite), mackintoshite, maitlandite, and hyblite were given in TEI-280, pp. 92-93. The study has been extended to include hydrothorite. All of these minerals are identical, are isostructural with thorite, and conform to the formula

$$Th_4(SiO)_{4-x}(OH)_{4x}$$

The mechanism of composition variation, in which $(OH)_4$ substitutes for SiO_4, is well known in the so called hydrogarnets. Work is now being completed on zircon and cyrtolite in which the same mechanism seems to operate. A report describing all of this work is in preparation.

The existing Harvard file of X-ray powder photographs of uranium mineral standards has been improved by rephotographing many of the films and the d-spacings of about half the films have been calculated. This work was done by Judith Frondel and Daphne Riska under Clifford Frondel's direction. Duplicates of many of the films have been obtained to fill gaps in the file of the Trace Elements Section Washington Laboratory. A complete set of X-ray powder mounts was prepared and has been loaned to S. C. Robinson of the Geological Survey of Canada to be photographed for his files. The same set has been loaned to the Trace Elements Section, Denver Laboratory for the same purpose.

The first printing of 2000 copies of the second revised edition of "A glossary of uranium-and thorium-bearing minerals", by Judith Weiss Frondel and Michael Fleischer (U. S. Geological Survey Circular 194, February 1952) was exhausted in September and a second printing has been authorized.

X-ray diffraction studies

by C. L. Christ

During this period the three main activities begun and pursued during the previous quarter and described in the last report on X-ray diffraction studies (TEI-280, pp. 76-82) were continued. These are: (1) study of the crystal structures and crystal chemistry of vanadate minerals; (2) study of the crystal structures of rare earth carbonates; (3) instrumentation for crystal structure analysis.

Vanadate minerals

Montroseite.--The determination of the crystal structure of montroseite has been completed by H. T. Evans, Jr., assisted by Stanley Block. Preliminary results of this study have been reported previously (TEI-280). The main features of the structure are listed in the following:

Montroseite, VO(OH)

Orthorhombic, 2/m

$a = 4.54 \quad b = 9.97 \quad c = 3.03$ A $\quad V = 137.1 A^3$

$a:b:c: = 0.455:1:0.304$

Space Group: $Pbnm = D_{2h}^{16}$, $Z = 4$

Atomic Coordinates:

4V in (c): $x\ 1/4\ z$; $\bar{x}\ 3/4\ \bar{z}$; $1/2 - x, 3/4, 1/2 + z$; $1/2 + x, 1/4, 1/2 - z$

$4O_I$ in (c); $4O_{II}$ in (c)

$X_V = -.051 \quad Y_V = .145$

$X_{O_I} = .203 \quad Y_{O_I} = .197$

$X_{O_{II}} = -.197 \quad Y_{O_{II}} = -.051$

The structure is the vanadium analog of diaspore. The presence of iron replacing vanadium in this structure is possible, but cannot be tested by a study of diffraction intensities. The presence of hydrogen is confirmed by the existence in the structure of an oxygen - oxygen distance of 2.70 A corresponding to a hydrogen bond. Other oxygen - oxygen distances are 2.95 to 3.00 A.

The structure described above corresponds to the sharp spots on the X-ray patterns. The X-ray patterns also show two sets of diffuse spots. The diffuse lattices are now under study and it seems that these may reveal shifts of positions of the vanadium atoms in the structure from one phase to the next. The chemical significance of these changes would appear to be of interest, and apparently are analogous to those occurring in the corresponding manganese structures, groutite and ramsdellite. A paper on the montroseite structure is being prepared by Evans and Block.

<u>"Lumsdenite"</u>.--A significant association of new vanadium oxide minerals, from the Colorado Plateau, collected and studied by T. Stern and L. Stieff has been subjected to single crystal investigation by H. T. Evans. One of the phases occurs as seams of radiated bladed structure, and very poor single crystal patterns have been obtained of this material. The substance is:

Orthorhombic

a = 3.7 A b = 19.0 A c = 3.0 A

Space Group: Pnam (prob.)

It is clearly related to montroseite with b-axis doubled. The analysis of the structure thus far indicates that it consists of zigzag double octahedron chains as found in montroseite and single octahedron chains of the rutile structure, which has been reported for V_2O_4. The composition consistent with this structure would be $V_2O_3 . V_2O_4 . H_2O$.

It is of interest to note that in the case of both monstroseite and "lumsdenite" the chemical formulas have resulted from structural analysis. It is difficult to get phases pure enough for chemical analysis.

There occur other phases in the same matrix in which the "lumsdenite" occurs. These are: (1) a second bronzy vanadium oxide, more granular in appearance, giving a distinct powder pattern; (2) a green powdery coating on the above oxide; (3) a black pitchy uranium mineral which gives a fair thorite pattern; (4) barite. Crystallographic studies on each of these is in progress.

Synthetic vanadates.--Synthetic work in the system $K_2O-V_2O_5-H_2O$ being carried out by I. Friedman and R. Marvin has yielded a number of crystalline phases which are now under X-ray study. Among these are:

a) α-KVO_3, orthohombic, space group Pmab,

$a = 5.69$ A $b = 10.82$ A $c = 5.20$ A $Z = 4$

These crystals are apparently isostructural with ammonium metavanadate NH_4VO_3, a tentative structure for which has been proposed by J. Lukesh of the General Electric Company. The α-KVO_3 structure will be determined and refined by S. Block at the Johns Hopkins University.

b) β-KVO_3, orthorhombic, space group Pnam,

$a = 8.223$ A $b = 13.54$ A $c = 3.698$ A $Z = 4$

The habit of the crystal suggests a chain structure.

like that proposed for NH_4VO_3. The structure is being investigated by C. L. Christ and H. T. Evans.

c) Polyvanadate crystals A, monoclinic, space group $P2_{1/n}$. The composition of these orange crystals has not yet been determined, but the structure probably contains a complex ion embodying six vanadium atoms, which may also be found in hummerite and other mineral structures. The structure analysis is being carried on by S. Block.

d) Polyvanadate crystals B, monoclinic space group $P2_{/n}$, $a = 13.82$ Å $b = 8.74$ Å $c = 10.72$ Å $\beta = 95^\circ 45'$. The composition of these crystals is undetermined, but it is probably closely related to the A crystals. The structure is being studied by H. T. Evans.

Several other phases have been isolated and are being characterized for further study.

Since investigations of the crystal structures of vanadium compounds are going on in other laboratories, it has been necessary to establish good liaison with these in order to avoid duplication of effort. A group, headed by Dr. William Barnes, at the National Research Council at Ottawa, Canada, is actively engaged in structure studies of certain vanadium minerals. They are investigating the structures of the hewettite minerals, the iron vanadate tentatively called "nolanite" at the U. S. Geological Survey, the rossite minerals, melanovanadite, brockebushite, pyrobelonite, pucherite, and descloizite. Evans visited Barnes and his group at Ottawa for several days in October.

Investigations on artificial vanadium-oxygen compounds are being carried out at the Crystallographic Laboratory at the University of Upsala, Sweden. A. Magneli of that group visited our laboratory in August. He is working on synthetic oxides, and I. Lindqvist of the same group on polyvanadates.

Rare earth carbonates

Sahamalite.--A paper on the new mineral sahamalite by H. Jaffe, R. Meyrowitz, and H. T. Evans has been prepared and is being processed.

Synchisite - Parisite Series.--Gabrielle Donnay, with the collaboration of J. D. H. Donnay, has continued her work on this series. This investigation has led to a good structural explanation for the somewhat anomalous morphological and optical characteristics found with these minerals. At the present time Mrs. Donnay is preparing a paper on the results of her X-ray diffraction studies and Howard Jaffe a companion paper on his mineralogic-petrographic studies. An explanation of the nature of the phenomena observed was given in TEI-280. The results obtained in the X-ray work require a rather lengthy table for presentation, as well as detailed definitions of the constants measured. It will suffice here to say that the original work has been greatly extended by the study of a large number of minerals and the details will be left for the published paper.

As a result of these studies it seems desirable to investigate the structures of members of the series. It does not appear possible to obtain good intensity data (necessary for the structural work) on natural material.

For this purpose synthetic crystals must be prepared. I. Friedman has already made some preliminary investigations in this direction. It is also fundamental to an understanding of the reasons why syntaxic intergrowth of various phases (defined by having different pseudo-cells) occur, to know the chemical compositions of the several phases involved. Here again analyzed synthetic material appears to be necessary, because of the impracticability of trying to separate the natural intergrown phases for analytical work.

Instrumentation for crystal structure analysis

IBM equipment.--In October the IBM Unit of the Geological Survey installed a type 602A Calculating Punch and since then H. T. Evans has been working to set a crystallographic computing program making use of punched-card techniques. A. L. Patterson at Philadelphia, and D. Harker and Mrs. B. Magdoff were visited by Evans in order to discuss with them their experience in using these methods. From the Watson Computing Laboratory in New York City a file of some 18,000 punched cards containing tables of trigonometric functions and other data useful in crystal structure analysis were obtained. The IBM Unit of the U. S. Geological Survey is now making basic tables from these for our work in crystallography.

Analog computer.--The selsyn motors for this computer have not yet been delivered. On their receipt, work on this computer will be resumed.

Future Work

Throughout this report it has been indicated which of the projects will require further work for their completion.

It is becoming apparent that with time more and more thought will perforce be given to the crystal chemistry and thence geochemical implications of the results being obtained. This means good and continuing liaison with the mineralogists and geochemists of the program. Every effort will be made to integrate our efforts into the overall program and to investigate those problems of significant interest.

It is planned to have Mrs. Donnay begin to concern herself with the structures of important uranium minerals. The work of Evans and Christ for the immediate future is fairly well dictated by existing program.

Publications by members of this project

1. J. D. H. Donney and Gabrielle Donnay, "Tables of Space Groups and Unit Cell Dimensions of Crystalline Substances", Pt. II, Geological Society of America Memoir (in preparation).

2. Gabrielle Donnay and J. D. H. Donnay, review of "A Thousand and One Questions on Crystallographic Problems", by P. Terpstra, Am. Mineral. (in press).

3. Gabrielle Donnay, Review of "Fouriersynthes von Kristallen", by W. Nowacki, Am. Mineral. (in press).

4. Gabrielle Donnay [a] and J. D. H. Donnay, "Symmetry Change in the High Temperature Alkali - Feldspar Series", Am. J. Sci. (October, 1952).

5. J. D. H. Donnay and Gabrielle Donnay, "Syntaxic Intergrowth in the Andorite Series" (in preparation).

6. Gabrielle Donnay, "Precision Determinations of Unit Cell Dimensions from X-ray Spectrometer Patterns", (in preparation, to appear as a TEI report).

7. H. T. Evans, Jr., and S. Block, "Crystal Structure of Montroseite", (in preparation).

8. H. Jaffe, R. Meyrowitz, and H. T. Evans, Jr., "Sahamalite, A New Rare Earth Mineral", (being cleared).

9. C. L. Christ, "Studies of Borate Minerals: I - X-ray Crystallography of Colemanite", Am. Mineral. (in press).

10. R. C. Hughes, P. P. Coppola, and H. T. Evans, Jr., b/ "Chemical Reactions in Barium Oxide on Tungsten Emmitters", J. App. Phys. 23, 635 (1952).

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a/ Contribution from the Geophysical Laboratory.

b/ Contribution from the Laboratory for Insulation Research, M.I.T.

GEOPHYSICAL PROSPECTING SERVICES AND RESEARCH ON METHODS AND PRINCIPLES

Development and maintenance of radiation equipment

By W. W. Vaughn

All radiation detection equipment used by Geological Survey field parties is maintained, calibrated, and distributed by the Radiation Laboratory of the Geophysics Branch. During the reporting period, commercial radiation detection instruments were modified to meet particular field needs. Development of new instruments and circuitry required for particular types and precision of radiation measurements was successfully completed, particularly the development of portable scintillation survey meters.

Portable gamma-ray logging units for small diameter drill holes were developed, utilizing both Geiger counters and scintillation counters as the detector element. The cable reels, weighing approximately 20 pounds, have a capacity of 1,000 feet of ¼-inch cable. The counting-rate meters, modified portable survey meters of the health physics type, have been calibrated semi-quantitatively in terms of the equivalent uranium. The gamma-ray log can also be used for stratigraphic correlation of subsurface formations.

Carborne scintillation detection equipment, based on the original model developed by the Oak Ridge National Laboratory, Health Physics Division, is now being constructed. Two shielded scintillation counters are used as detectors and are mounted on the car roof so that the detectors scan only the area adjacent to the road and do not measure the radioactivity of the road itself. The total counting rate is recorded on an

Esterling-Angus graphic milliameter driven by the speedometer cable. The sensitivity of the equipment is sufficient to resolve a difference of 0.001 percent equivalent uranium in broad sources such as shales, sandstones, and other lithologic units.

The Geological Survey plans to replace portable Geiger counters by the newly-developed portable scintillation counters. Extensive testing and developing of various scintillation counter circuits have been done both in connection with the procurement of portable scintillation survey meters, AEC Contract AT-(49-1)-696 (Nuclear Research Corp.) and USGS Contract GS-08S-2237 (Precision Radiation Instruments Co.), and in establishing a suitable circuit modification for converting present Geiger counters to scintillation survey meters.

To date, only the portable scintillation survey meter, Model 111, made by Precision Radiation Instruments has been accepted as meeting contract specifications. The scintillation meter, Model SM-3A, made by Nuclear Research Corp., still has numerous defects and has not been accepted. Full delivery of all instruments on the Prec. Rad. Inst. contract is anticipated in January; delivery by Nuclear Research Corp. is not anticipated before April 1953.

Physical behavior of radon
by Henry Faul and A. S. Rogers

As part of the study of the physical behavior of radon undertaken to determine how and why radon moves in rocks and soils, a preliminary survey of the radon content of the Dillon Tunnel Miners' Basin, North LaSal Mountain, Grand County, Utah was completed and evaluated by Faul and Hunt (TEM-354). An average radon content of 5,000 micromicrocuries/liter was observed, and the distribution of radioactivity appears to be related in an orderly way to the magmatic series consisting of several facies of syenite porphyry including some alkalic dikes.

Precise apparatus for the systematic study of radon content in gas and liquid samples was constructed by Allen S. Rogers and set up at the University of Utah. The apparatus is now undergoing preliminary tests and calibration. A series of samples of bottom water brine from various oil and gas wells is being furnished by the Phillips Petroleum Co., together with the results of chemical analysis of each sample. The waters are being analysed for radium and uranium.

A literature search for available data on the physical chemistry of radon is in progress. Although the literature on the subject is large, it is expected that most of the data are unreliable because most measurements were made with inadequate apparatus in the early days of nuclear physics. A systematic study of phase relationships of radon in air and water probably will have to be undertaken if only to verify existing data.

Absorption and scattering of gamma radiation

by Henry Faul

Investigation of the scattering and absorption of gamma radiation to clarify ultimately measurements in gamma-ray well logging and airborne radioactivity surveying has included experimental measurements on a cooperative basis at the National Bureau of Standards and at the Oak Ridge National Laboratory; experimental measurements were also made in simulated drill holes at Grand Junction, Colo. Analysis of the experimental data obtained at the Bureau of Standards in 1950 and 1951, and at Oak Ridge in 1951 on the gamma-ray distribution in cylindrical geometry has not been completed. The final report on this phase, to be submitted for publication, is now in preparation. Further analysis of experimental data and additional measurements to fill gaps in the present data are planned for the next half year.

The results of the work can be broken up into two parts--discussions of the point source and the continuous source distributions. The former constitutes the raw data, and the latter constitutes the data integrated over appropriate geometries.

Point source

The experiments performed showed that the radiation intensity at the center of a cylindrical cavity (simulated drill hole) from a point source immersed in absorbing medium varied in a rather complex manner, not merely dependent on the absolute distance and the amount of absorbing material (water) between the source and the detector. At very far distances from the detector (120 cm. of water) the intensity becomes a function only of the distance and the amount of absorber. The decay is purely exponential, indicating that the contribution from the scattered radiation is proportional to the distance squared. Ra, Co^{60}, and Cs^{137} all exhibit similar behavior, the order of effective hardness being given above.

Extended source

The results of the experiment were then integrated for a fixed height, Z, above the equatorial plane of the counter, over a plane extending from the edge of the pipe to infinity. The results then can be considered as the radiation intensity from infinite plane sources coaxial with the hole at various heights above the counter. These were found to be readily expressible as sums of exponential and Gaussian functions of Z. It was found that the larger the diameter of the hole, the more slowly does the intensity decrease with increasing Z.

The above results were then integrated over various intervals in Z, from zero thickness to infinite thickness. Curves are calculated for the intensity in the hole from various thicknesses of the sources and distances of the detector from these sources.

Finally, the intensities for the infinite thicknesses were plotted as functions of the hole radii. It is found that the counting rate increases linearly with the radius. A cased well (iron pipe) shows the same behavior, but the slope is less steep.

Comparison with synthetic drill holes

Counting rates were recorded in several synthetic drill holes at Grand Junction, with the same type counter as was used at the National Bureau of Standards. Preliminary calculations indicate that the measurements in the holes fit the semi-empirical expression for gamma ray intensity derived from point source behavior.

Airborne radioactivity surveying
by R. M. Moxham

As the result of airborne radioactivity surveys during the period from June through November 1952, two new areas in which uranium was not heretofore known to occur, were located—the Miller Hill area in southwest Carbon County, Wyo., and the Devils Tower area in Crook County, Wyo. Airborne surveys were undertaken in six states and totalled 20,600 traverse miles, of which 11,190 traverse miles were flown as scheduled radioactivity surveys and 9,410 traverse miles were flown as scheduled aeromagnetic surveys with concurrent radioactivity surveys.

Arrangements have been completed to obtain a Douglas C-47A from the U. S. Air Force on an indefinite loan basis. This aircraft will supplement our present Douglas DC-3 and will permit us to achieve the proposed rate of radioactivity surveying, namely about 18,000 to 24,000 traverse miles per year. Transfer of the aircraft to the Geological Survey should be accomplished in December 1952 and, barring unforeseen delays, the modification of the aircraft to accommodate the scintillation detection equipment, the Sonné continuous-strip-film camera, and the 180° spherical-lens sighting device should be completed by late Spring of 1953.

The design of the scintillation detection equipment has been essentially frozen, and sufficient additional equipment plus spare parts has been assembled by Oak Ridge National Laboratory for installation in the second aircraft. A final report summarizing the development of equipment and the experimental data bearing on the absorption and scattering of gamma radiation in air is in preparation.

Areas surveyed

The areas surveyed from June 1 through November 30, 1952, shown on the attached map (fig.16), are listed below with an explanatory note for each area.

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

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SECURITY INFORMATION

UNITED STATES
BASE MAP

NO.	STATE	AREA
1	ARIZONA	DEFIANCE UPLIFT
2	ARIZONA	CARRIZO MOUNTAINS
3	COLORADO	DENVER BASIN
4	MAINE	DEAD RIVER-KATAHDIN
5	MINNESOTA	
6	NEW MEXICO	TODILTO
7	WYOMING	PUMPKIN BUTTES
8	WYOMING	DEVILS TOWER
9	WYOMING	MILLER HILL
10	WYOMING	EVANSTON
11	WYOMING	NORTH SPLIT ROCK
12	WYOMING	TABERNACLE BUTTES
13	WYOMING	ASPEN MOUNTAINS
14	WYOMING	WEST LONE TREE
15	WYOMING	RED DESERT

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AIRBORNE RADIOACTIVITY SURVEY PROJECTS

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Fig 16

72498

Base compiled by U. S. Geological Survey
Projection and shore line by the U. S. Coast and Geodetic Survey
Albers equal-area projection
North American datum

State	Area	Traverse miles
Arizona		
	Defiance Uplift, Apache County: Survey of about 700 square miles of sedimentary rocks ranging from Permian through Eocene. Also includes some volcanic and intrusive rocks. Nineteen radiation anomalies were detected. Several of which were field checked are apparently due to slightly radioactive igneous rocks.	2,800
	Carrizo Mountains, Apache County: Approximately 200 square miles were surveyed. The area is underlain chiefly by Mesozoic sediments, volcanics, and intrusives. Three anomalies were detected but have not yet been field checked.	800
Colorado		
	Denver Basin area, El Paso, Elbert, and Weld Counties: Surveys were made over coal-bearing sediments of the Wasatch formation in El Paso and Elbert Counties and over Cretaceous rocks of the Montana group in Weld County. No anomalies were detected.	400
Maine		
	Dead River and Katahdin areas, Piscataquis, Franklin, Somerset, and Oxford Counties: Flown in conjunction with magnetometer surveys for metallic deposits. No radiation anomalies were recorded.	3,400
Minnesota		
	Roseau, Kittson, Marshall, Remington, Polk, and Red Lake Counties: Flown in conjunction with magnetic surveys for metallic deposits. No radiation anomalies were detected.	6,010
New Mexico		
	Todilto area, McKinley, Sandoval, San Juan, and Valencia Counties: Survey of the Todilto limestone, Dakota sandstone and carbonaceous rocks. No anomalies of significance were detected.	810

State	Area	Traverse miles
Wyoming		
	Pumpkin Buttes area, Johnson and Campbell Counties: Surveys included about 850 square miles underlain by sedimentary rocks of the Wasatch and White River formations. Sixty-four anomalies were detected.	3,500
	Devils Tower area, Crook County: Survey of about 75 square miles of Cretaceous and Eocene rocks of the Lakota, Dakota, and Lance formations. Five radiation anomalies were recorded. Uranimum-bearing sandstone was found at two of these localities.	300
	Miller Hill area, Carbon County: Survey of 90 square miles underlain by Mesozoic and Eocene sediments. Ten radiation anomalies were detected. Uranium-bearing limestone occurs at several of the localities.	360
	Evanston area, Uinta County: Cretaceous and Eocene coal-bearing rocks. No anomalies were recorded.	220
	North Split Rock area, Fremont and Natrona Counties: White River formation, some Pre-Cambrian metamorphic and Tertiary intrusives. No anomalies detected.	400
	Tabernacle Buttes area, Sublette County: Coal and other Eocene rocks. Five radiation anomalies were detected. No field checks have been made as compilation is still in progress.	440
	Aspen Mountains, Sweetwater County: Cretaceous and Eocene sediments, including coal. Three radiation anomalies detected. No field checks made. Compilation in progress.	460
	West Lone Tree area, Uinta County: Green River and Bridger formation of Eocene age. One anomaly detected has not been checked, pending compilation.	300
	Red Desert area, Sweetwater County: Mostly Cretaceous and Eocene rocks with lignite and a few intrusives. Three anomalies recorded have not yet been ground checked, pending compilation.	400

Summary of airborne surveys

State	Traverse miles	
	Radiation	Magnetic-radiation
Arizona	3,600	--
Colorado	400	--
Maine	--	3,400
Minnesota	--	6,010
New Mexico	810	--
Wyoming	6,380	--
	11,190	9,410

Discussion of significant areas

Approximately 3,500 traverse miles were flown in the vicinity of Pumpkin Buttes in the Powder River Basin, Johnson and Campbell Counties, Wyoming. The surveys made during the reporting period extended the coverage of the airborne radiation surveys of October 1950, during which the uranium in this area was first detected. The recent survey recorded 64 anomalies of which at least 23 were found to be small areas of relatively high radioactivity. Carnotite-bearing sandstones containing more than 0.1 percent uranium were found at several of these localities.

An airborne survey covering 90 square miles in the Miller Hill area in the southwest Carbon County, Wyo., recorded 10 radioactivity anomalies. Preliminary field investigation showed that some of the anomalies were due to uranium-bearing limestone of Miocene age, containing as much as 0.15 percent uranium.

A survey of 75 square miles in Crook County Wyo., northwest of Devils Tower, recorded 5 radioactivity anomalies. Preliminary field work showed that two of the anomalies were due to uranium-bearing sandstone.

The two new areas of uranium occurrences found by airborne surveys during the reporting period -- northwest of Devils Tower and in the Miller Hill area -- are of definite interest. The airborne surveys in both areas were done on a sampling basis and covered only a relatively small portion of the recommended areas. Additional surveys are planned for the next field season to complete the coverage in both areas. Additional flights will also be made in the Powder River basin north of Pumpkin Buttes to delimit the area of uranium deposition on the north.

Gamma-ray logging, Colorado Plateau

by K. G. Bell

Gamma-ray logging of drill holes results in: (1) quick quantitative appraisals of the uranium contents of ore-bearing formations, and (2) the detection of uranium daughter products found down dip from ore bodies that provide a guide to ore.

Gamma-ray logging of holes drilled through the carnotite-bearing Salt Wash member of the Morrison formation is done as a service function for the Colorado Plateau Exploration project. The number, distribution, and footage of such holes logged during the period of July 1 to November 22, inclusive, are as follows:

EXPLORATION AREA	NO. OF HOLES	FOOTAGE LOGGED
Atkinson Mesa	82	30,079
Dolores Bench	20	3,504
Gypsum Valley	205	22,967
Jo Dandy	87	24,006
La Sal Creek	26	4,556
Long Park	144	28,828
San Miguel Bench	77	20,907
Spring Creek Mesa	48	16,925
Yellow Cat	86	13,355
	775	165,127

Nineteen holes having an aggregate footage of 3,354 feet which were drilled by the U. S. Vanadium Corporation in the Jo Dandy area, and five holes having an aggregate footage of 312 feet which were drilled by independent operators in the Gypsum Valley area, were logged.

Gamma-ray logging of shot holes drilled by a seismic exploration party of the Shell Oil Company which was operating in the Northwest Carrizo area, Apache County, Ariz. and San Juan County, Utah was done during July, August, and September. During this time 140 holes having an aggregate footage of 16,135 feet were logged.

Development

One light-weight gamma-ray logging unit with capacity for 2,000 feet of 0.25-inch diameter cable has been constructed and mounted in a Jeep station wagon. This unit will be used mainly on projects in remote areas.

Interpretation and processing of data

Grade estimates in terms of eU_3O_8 were determined from anomalies appearing on gamma-ray logs of the following listed holes:

Exploration area	Hole numbers
Atkinson Mesa	1 to 121, inclusive
Calamity Mesa	1 to 730, inclusive
Charles T.	1 to 742, inclusive
Dolores Bench	1 to 183, inclusive
Gypsum Valley	1 to 179, inclusive
Jo Dandy	1 to 120, inclusive
La Sal Creek	1 to 173, inclusive
Radium group	1 to 374, inclusive
San Miguel Bench	1 to 121, inclusive
Upper group	1 to 186, inclusive
Yellow Cat (core drill)	1 to 324, inclusive
Yellow Cat (wagon drill)	1 to 166, inclusive
	3,419 holes

Iso-radioactivity contour maps of the ore-bearing sandstones have been made for the Yellow Cat, La Sal Creek (Gramlich Group), and Spud Patch areas. This work was done experimentally for the purpose of determining whether or not significant directional trends of the mineralized parts of the sandstones would be revealed and to determine whether or not anomalous radioactivity highs coincide with areas considered favorable on the basis of geologic criteria. Two contour maps of each area were made, one based on the maximum counting rate for anomalies appearing on gamma-ray logs of drill holes penetrating the ore-bearing sandstones, and the other based on the areas under the curves for anomalies on the logs. The two maps are nearly identical. A preliminary appraisal indicates this kind of mapping can be useful in locating ore bodies.

Several copies of the Barnaby calibration chart were transmitted to the Colorado Plateau Exploration project during July. The field geologists now use these charts for making semi-quantitative estimations of grade and thickness. Quantitative determinations are being made by personnel in the Radiometric Logging Unit office.

A map showing the significant results of the gamma-ray logging of shot holes in the Northwest Carrizo area is being prepared for transmittal to the A.E.C. By request of the Shell Oil Company only one copy of the map is to be transmitted at this time.

RESOURCE STUDIES

by A. P. Butler, Jr. and R. W. Schnabel

Objectives

Resource studies at the program level have as their objectives: (1) compilation of data on the distribution, size, quality, and other characteristics of domestic resources of uranium and thorium for use in planning new investigations and to provide summaries of such resources; (2) analysis and collation of these data to yield hypotheses and principles that can be applied to more effective search for new deposits; and (3) provision of a ready source of information on uranium and thorium resources for use in replying to requests for information from the Commission, other government agencies, and the public.

The principal intermediate objective is the summary, compilation, and organization of data in reports of the Geological Survey, the Atomic Energy Commission and its contractors into useful reference form. The initial step in this work is abstracting data on the various mining properties and districts onto cards arranged for cross-indexing, and plotting data from these cards onto maps.

Status of work

As of December 1, information pertaining to about 2,400 localities had been entered, duplicated and organized in the file. Copies of all but about 200 of these cards have been transmitted to the AEC Raw Materials Office of the Atomic Energy Commission in New York City, the Washington office of the Atomic Energy Commission and the Denver Office of the U. S. Geological Survey.

A map showing localities in the United States that have been examined for radioactivity, up to June 30, 1952, has been prepared at a scale of 1:2,500,000. Problems and methods of satisfactory reproduction of the map are being reviewed.

Future Plans

The immediate plans of the resource group involve the completion of abstracting the backlog of reports contained in this office, so that they may serve not only as an index of deposits that have been examined but will also contribute materially to summarizing, correlating, and synthesizing existing knowledge of uranium deposits.

Projects planned include the preparation of a published map showing localities investigated for radioactivity, various working maps showing the distribution of uranium deposits and review and study of data in resource card file and related information to determine how they may be applied most effectively to problems of general resource appraisal and development of useful principles.

DETAILED LIST OF INVESTIGATIONS

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