DEPARTMENT OF THE INTERIOR

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GEOLOGIC INVESTIGATIONS OF RADIOACTIVE DEPOSITS

Semiannual Progress Report—June 1 to November 30, 1954

This report is preliminary and has not been edited or reviewed for conformity with U. S. Geological Survey standards and nomenclature.

December 1954

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This report concerns work done on behalf of the Divisions of Raw Materials and Research of the U. S. Atomic Energy Commission.

UNITED STATES DEPARTMENT OF THE INTERIOR

GEOLOGICAL SURVEY

GEOLOGIC INVESTIGATIONS OF RADIOACTIVE DEPOSITS

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Trace Elements Investigations Report 490

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INTRODUCTION

Since 1947 the Geological Survey, under the sponsorship of the U. S. Atomic Energy Commission, has undertaken investigations of radioactive materials in the United States and Alaska, and to a minor extent in foreign countries. This report is a statement of progress during the six-months period from June 1 to November 30, 1954, and gives the principal information developed during that period. Many of the investigations discussed herein have advanced to the point where final reports are in preparation for future publication with the permission of the AEC. Other studies are still incomplete and the final reports cannot be expected for several years.

The principal investigations by the USGS continued to be in the Colorado Plateau region of Colorado, Utah, Arizona, and New Mexico. The drilling program on the Plateau was continued, but no exploration was undertaken elsewhere during the period.

Formal publications (as distinguished from administrative Trace Elements Reports) during this period, resulting from work done previously, consisted of four bulletins or bulletin chapters, 12 USGS Circulars, and 22 papers, including abstracts, in technical journals. Three Trace Elements Reports, two of which will be sold to the public, were made available through the Technical Information Service of the AEC, and five additional such reports have been sent to the Technical Information Service but are not yet available. Thirty-two papers were presented by staff members before scientific societies, and 40 Trace Elements Reports and miscellaneous papers and maps have been placed on open file in libraries throughout the country where they may be consulted by the public.

The highlights of the main field and laboratory projects underway are contained in the Summary on pages 18 to 24.

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SUMMARY

Uranium in sandstone-type deposits

Colorado Plateau

Geologic mapping

On the Colorado Plateau, geologic mapping was continued at Elk Ridge, Utah; San Rafael Swell, Utah; and the western San Juan Mountains, Colo. New mapping projects were started in Lisbon Valley, Utah and Colo.; Moab-Inter-River area, Utah; Abajo Mountains, Utah; Circle Cliffs, Utah; and Sage Plain, Utah and Colo.

In the San Rafael Swell four northwest-trending river-channel systems were found, a number of the channels within each system containing radioactive material. In the Lisbon Valley area the larger uranium deposits in the Salt Wash member of the Morrison formation in East Canyon lie in a narrow southwest-trending belt which may extend into the western Abajo Mountains; another similar belt of favorable ground trends southeasterly and the two belts may intersect beneath the north edge of Sage Plain. A rock unit that may represent an early Shinarump drainage system was found in the Circle Cliffs, but no radioactivity anomalies have been noted in it. Uraniferous material has been found in the Moenkopi formation, Shinarump conglomerate, and the Chinle formation within the Circle Cliffs proper and in the Salt Wash member of the Morrison formation along the east margin of the Circle Cliffs anticline. In the Abajo Mountains two types of uranium deposits occur in the Salt Wash sandstone; one type is small and pod-shaped, the other relatively large and tabular. Uranium deposits in the Elk Ridge area occur in the Moenkopi formation, Shinarump conglomerate, and Chinle formation. In the Sage Plain area many scattered uranium-vanadium deposits occur in one or more ledges of the sandstone in the upper part of the Salt Wash member. In the Western San Juan Mountains area the uranium appears to be more abundant near the margins of thick parts of the vanadium-uranium layer in the Entrada sandstone.

During the report period photogeologic maps of fifty-seven $7\frac{1}{2}$-minute quadrangles were completed, bringing the number of such maps made since the beginning of the program in 1951-52 to 241, of which 182 are now available for public inspection.

Stratigraphic studies

Study of Triassic and associated formations shows that the known uranium deposits in the Cutler formation occur in an undifferentiated arkose facies. A microscopic study of sandstones in the Shinarump conglomerate and the Moss Back member of the Chinle formation indicates that strata of sandstone containing 15 to 35 percent kaolin are more favorable for the deposition of uranium than strata containing less than 15 percent kaolin.

Geobotany

Brief studies were made of plant associations at Myton, Duchesne County, Utah; Poison Buttes, Carbon County, Wyoming; Sanastee, San Juan County, New Mexico; and Pojoaque, Santa Fe County, New Mexico. Experimental plot studies were continued near Santa Fe, New Mexico. Combinations of carnotite, selenium, sodium vanadate, gypsum, lime, potash, and phosphate were added to the soil. Nine species of plants were grown to maturity in plots favorable for their growth.

Mineralogy

Paragenetic studies on the Jo Dandy group show that the mineralogic sequence follows the oxidation sequence of Garrels and Weeks; the mineralogy is typical of uranium-vanadium deposits. Among the minerals present are montroseite, coffinite, and secondary minerals.

Relations of ore minerals to gangue minerals are still under study. The fine-grained, vanadium-bearing silicates generally present in the ore sandstones include chlorite, roscoelite, and vanadium hydromica. Studies of selenium in pyrite and marcasite show that more is present in marcasite than in pyrite.

New data were determined and work is in progress on "doloresite", sodium vanadate, iron vanadyl vanadate, calcium hypo vanadate and two other new minerals from the Peanut mine.

The clay mineralogy of the Triassic formations is being studied to determine the regional and vertical variations in clay mineral content.

Distribution of elements

Two types of regional patterns are shown by concentrations of trace elements in sandstone-type uranium deposits. One pattern shows regional "highs" partially coincident with the region of salt structures; the other pattern shows regional "highs" in the northwestern half of the Colorado Plateau. Preliminary results suggest that the relative size of ore bodies may be predicted from their trace elements compositions.

Geophysics

Standard electric logging was conducted at Holbrook, Arizona; Monogram Mesa, Colorado; and Holiday Mesa, Utah. Experimental surface-inhole electrical resistivity investigations were conducted at Holbrook, Arizona and Deer Flat, Utah, a wide variety of electrode arrangements being used. Seismic refraction studies were made at Holiday Mesa, Utah; Mitchell Mesa, Arizona; Deer Flat, Utah; and Oljeto Wash, Arizona.

Experimental shallow reflection surveys were conducted at Nokai Mesa, Arizona; Deer Flat, Utah; and Monogram Mesa, Colorado. New experiments using pattern shooting and multiple geophone techniques, will be conducted during the next six months.

Aeromagnetic surveys covering about 20,000 square miles have been flown during the report period, of which 3,900 square miles were flown during October 1954. About 1,000 gravity stations have been established in an area totalling about 4,000 square miles.

South Dakota and Wyoming

In the southern Black Hills, South Dakota, geologic mapping of an area of approximately 140 square miles was completed and the Gould and Livingston mines were mapped. The areal geologic mapping supports the concept that structure is a factor in the localization of the ore deposits; the largest known deposits in the area are in a large structural terrace in the Flint Hill quadrangle, and most of the production to date has been taken from a small structural terrace between Craven and Coal Canyons. Mapping of the lithology of the Inyan Kara group also resulted in the definition of a number of elongate bodies of sandstone, most of which appear to represent stream channels.

Geologic mapping of the Devils Tower area, Wyoming and Montana, was resumed. Carnotite-type deposits in a sandstone are present in a belt of radioactivity anomalies 10 to 20 miles wide that extends across parts of the Moorcroft, Devils Tower, and Aladdin quadrangles. Uranium ore is now being mined in parts of the Moorcroft and Devils Tower quadrangles.

Near the Pumpkin Buttes in the Powder River Basin, Wyoming, a definable area is characterized by dominantly red sandstone lenses near the middle of the Wasatch formation. The uranium-bearing sandstones are associated with this zone, and the larger uranium deposits so far mined are near the boundary of the red sandstone.

In the Crooks Gap area, Fremont County, Wyoming, uranium deposits in the Wasatch (?) formation are associated with fine-grained carbonaceous beds or lenses, and with red and brownish-yellow iron-stained sandstones in the lower part of the formation. In the Gas Hills area, also in Fremont County, most known occurrences of uranium are in the upper coarse-grained part of the Wind River formation of Eocene age, which rests with angular discordance on rocks ranging in age from Cambrian to Paleocene.

Uranium in limestone

Uranium minerals have been found in the Edwards limestone in Upton County, Texas, and in the Hueco Mountains, El Paso and Hudspeth Counties, Texas. In the Hueco Mountains area carnotite is associated with mammillary deposits of secondary calcite, coating limestone pebbles and filling cracks in caliche.

Uranium in veins, igneous rocks, and related deposits

In the Central City-Georgetown area, Colorado, about 50 square miles and about 200,000 linear feet of underground workings have been mapped and all mine dumps and accessible mines have been checked for radioactivity. Conclusions from the study are: (1) although uranium is widespread in this part of the Front Range, individual deposits are small; (2) a few mines may be expected to produce from a few to several hundred tons of uranium ore; and (3) pre-Cambrian pegmatites may prove to be a substantial source of low-grade uranium ore.

In the Ralston Buttes district, Colorado, about 20 uranium occurrences have been found and one property is now in production. All the significant occurrences of pitchblende are associated with base-metal sulfides in or near carbonate-bearing breccias of probable Tertiary age. Most of the deposits seem to be localized in fault structures where the faults cut pre-Cambrian layers rich in hornblende, biotite, or lime-silicate minerals.

Uranium in carbonaceous rocks

Reconnaissance mapping and preliminary analytic data indicate that approximately 460 acres in the North Cave Hills, Harding County, South Dakota, are underlain by lignite averaging 1.4 feet in thickness and containing about 0.20 percent uranium. Concentrations of uranium in excess of 0.10 percent are present in lignite and carbonaceous shale of the Ludlow member of the Fort Union formation in the Slim Buttes area, also in Harding County.

About 75 channel and grab samples of black shale were collected from the Woodford chert in the Arbuckle Mountains area of southern Oklahoma; from the correlative of the Woodford in the Llano area of Texas; and from cores of the Woodford in Andrews and Borden Counties, Texas. The Woodford is a correlative of the Chattanooga shale of Tennessee and Kentucky.

Geochemistry

In uraniferous coals, it appears that uranium is retained by substances similar to humic acids, probably ionic uranyl humates. Studies of crude oil, oil-impregnated sandstone, carbonaceous uranium ore, and carbonaceous pellets from the Temple Mountain area, Utah, indicate that oil migrating through a uraniferous zone can pick up and carry uranium.

Coalified wood with usually high percentages of germanium and uranium was found in the Chattanooga and Cleveland shales.

Three black shales were fractionated by ball-mill grinding in mixed media into organic-rich and inorganic-rich fractions and a middlings fraction of colloidal or nearly colloidal size. Most of the uranium is in the middlings fractions, suggesting that the uranium is present in a separate colloidal phase disseminated through the organic matrix. Similar studies of shale from the Dakota formation, New Mexico, show that uranium is associated with the carbonaceous constituents.

Uranium in phosphate

Northwest phosphate

Previously unreported occurrences of the Phosphoria formation were found at one locality in western Utah, another in eastern Nevada, and a third in north-central Idaho. Phosphate deposits of possible economic importance occur in the upper part of the Rex member near Victor, Idaho; other promising phosphate deposits were sampled near Elliston, Garrison, Maxville, and Divide, Montana. A secondary uranium mineral, probably tyuyamunite, is present in the upper phosphate zone of the phosphatic shale in the Crawford Mountains, Utah.

Florida phosphate

A geologic study of the phosphate deposits and phosphatic sediments in Florida outside of the land-pebble district was started in July 1954, in order to investigate the nature, extent, and origin of the deposits, and the distribution of uranium in them and in the aluminum phosphate zones.

Mineralogy

It was established that uranium in apatite from sedimentary and crystalline rocks is mainly tetravalent. It is proposed that uranium is originally emplaced in apatite as U^{+4} substituting for Ca^{++} in the structure and that the hexavalent uranium occurring in apatite is the result of weathering and of auto-oxidation during radioactive decay.

Reconnaissance for uranium in the United States

A uranium deposit in Permian Red Beds near Randlett, Cotton County, Oklahoma, is in a sandstone lens approximately 300 feet wide, 25 feet thick, and 600 feet long. The lower ten feet of the lens contains torbernite, autunite, uranophane, carnotite, and bayleyite (?) associated chiefly with malachite and azurite in heavily iron- and manganese-stained rock. Analyses indicate a uranium content of 0.004 to more than 1 percent. Near Manitou, Tillman County, Oklahoma, beds of an "arkosic sandstone" of the Permian Red Beds show uranium minerals in beds 5 to 10 feet thick which are heavily stained with iron, manganese, and asphalt. Channel samples contain 0.06 to 0.11 percent.

Autunite and meta-autunite have been found coating fracture surfaces in bedded gypsum and gypsiferous clay in the White River group in Dawes County, northwestern Nebraska.

Analytical service and research on methods

Photographic and radiometric methods are being investigated for a method of thorium analysis, and research was undertaken on a method of isotope abundance analysis by pile irradiation.

A spectrographic method was developed for the determination of strontium in phosphate rock, a method for calibrating the light filters used in fluorimeters was applied, and studies of the hafnium-zirconium ratio were completed. A method for the determination of fluorine in silicate rocks, especially useful in the analysis of "leached zone" phosphate samples, was developed, as was a spectrophotometric method for the determination of uranium which covers the intermediate uranium range which is below the optimum range for volumetric and above the optimum range of the fluorimetric method. A method was also developed for isolating carbon from fossil bone for C^{14} determination.

Geochemical and petrological research on basic principles

Study of the distribution of uranium in rocks of several petrographic provinces was completed. The rocks are from the Modoc lavas, Boulder batholith, Highwood and Bearpaw Mountains, Sierra Nevada, and the Idaho batholith. Alkalic rocks from New Jersey were also studied. The uranium content of the major and accessory minerals was determined for rocks from the Sierra Nevada and the Idaho batholith.

Chemical work on a channel sample from the Mineral Joe mine, Jo Dandy area, suggested conclusions that are consistent with a primary low-valent mineral assemblage that has been oxidized in situ by atmospheric oxygen. The Eh-pH apparatus continued in operation and additional information pertaining to vanadium oxidation was obtained. Studies of the vanadiferous clays were continued.

Studies continued on the determination of the evolution of the isotopic composition of lead in the crust of the earth. Five types of rocks are being investigated as possibly representing the original crust. As an independent line of evidence efforts are being made to concentrate enough zircon for age determinations from certain anorthosites.

Significant advances were made in crystal chemistry and structure studies as applied to uranium and vanadium of the Colorado Plateau. Crystal structures of liebigite and rutherfordine, both uranyl carbonates, and a new vanadium mineral related to meta-autunite and tyuyamunite were investigated. The composition of the decavanadate complex represented by the minerals hummerite and pascoite was established.

Geophysical prospecting and research

Research and development of radiation detection equipment has centered mainly on a jeep-mounted scintillation logger of high sensitivity, a liquid phosphor scanning device, a modified carborne scintillation detector, an "emanation discriminator" for pulse height analysis, and a mixing circuit to permit parallel operation of crystal detectors. Modification of the modified gamma-ray logger has been completed and a new chart for determining grade and thickness is now in use by all the Colorado Plateau logging units.

Airborne radioactivity surveys totalling 35,622 traverse miles were made in Alaska, Arizona, Colorado, Maine, Montana, Oklahoma, Pennsylvania, Utah, and Wyoming. Many anomalous localities were detected in an area of 150 square miles north of the Yampa River in Moffat County, Colorado. Anomalies were also found in the Devonian belt, Maine; the Myton area, Utah; and the East Pine Ridge escarpment, Tisdale and Pine Mountain areas, Wyoming.

URANIUM IN SANDSTONE-TYPE DEPOSITS

Colorado Plateau geologic studies

Regional geologic mapping

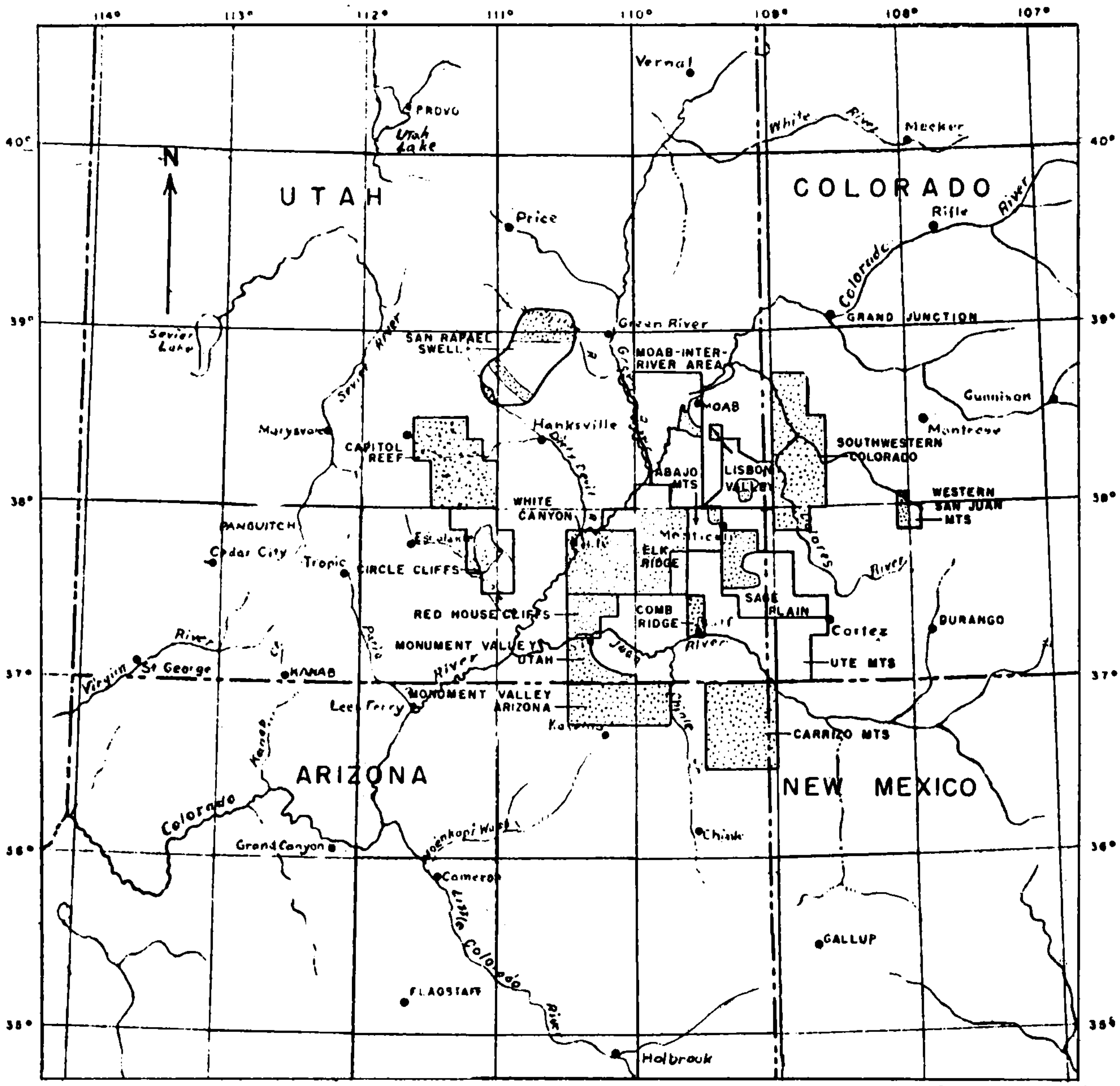
Prior to this report period field work was completed for the following quadrangle mapping projects: Southwestern Colorado area; Monument Valley area, Ariz.; Red House Cliffs area, Utah; White Canyon area, Utah; and Capitol Reef area, Utah. The strip-mapping project in the Monument Valley area, Utah, was also completed (fig. 1).

During this report period field and office work was continued on the Elk Ridge area, Utah, quadrangle mapping project, and the San Rafael Swell area, Utah, strip-mapping project (fig. 1).

Work was started on five mapping projects during this period: Lisbon Valley area, Utah and Colo.; Circle Cliffs area, Utah; Abajo Mountains area, Utah; Sage Plain area, Utah and Colo. (all quadrangle mapping projects), and the Moab-Inter-river area, Utah (strip-mapping project), (fig. 1).

Southwestern Colorado quadrangle mapping, by F. W. Cater, Jr.

The last of the 18 quadrangle maps reporting the results of this work were transmitted during this report period: TEM-706, "Geology of the Roc Creek quadrangle, Colorado," by E. M. Shoemaker; TEM-701, "Geology of the Juanita Arch quadrangle, Mesa County, Colorado," by E. M. Shoemaker; and TEM-707, "Geology of the Uravan quadrangle, Montrose County, Colorado," by F. W. Cater, Jr., A. P. Butler, Jr., and E. J. McKay, with a section on "The Mines" by R. L. Boardman.



AREA TO BE MAPPED

AREA OF MAPPING COMPLETED, NOVEMBER, 1954

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

0 — 100 MILES

Carrizo Mountains area, Ariz.-N. Mex. quadrangle mapping, by J. D. Strobell, Jr.

Field work was completed in fiscal year 1954; the geologic map in preliminary form has been transmitted. A preliminary appraisal of the uranium deposits was also transmitted in 1952. A paper entitled "Stratigraphic relations in the Carrizo Mountains area, northeastern Arizona and northwestern New Mexico," was presented at the annual meeting of the Geological Society of America in November 1954.

Monument Valley area, Ariz. quadrangle mapping, by I. J. Witkind

Field work was completed in fiscal year 1953. During this report period two reports were transmitted: TEI-340, "Localization of uranium minerals in channel sediments at the base of the Shinarump conglomerate, Monument Valley, Arizona," and TEM-577, "Recommendations for an exploration program on Mitchell Mesa, Monument Valley area, Arizona." A talk entitled "Localization of uranium minerals in channel sediments at the base of the Shinarump conglomerate, Monument Valley, Arizona," by I. J. Witkind, was presented at the GSA meetings in November 1954.

Monument Valley area, Utah strip-mapping, by R. Q. Lewis, Sr.

Field work was completed in fiscal year 1953 and four reports have been transmitted.

Red House Cliffs area, Utah quadrangle mapping, by T. E. Mullens

Field work was completed in fiscal year 1954 and two reports have been transmitted.

Comb Ridge area, Utah quadrangle mapping, by J. D. Sears

Field work on this project, which was financed entirely by USGS funds, was completed in 1953 and a preliminary report, TEM-671, was transmitted.

White Canyon area, Utah quadrangle mapping, by A. F. Trites, Jr.

Field work, except for spot-checking, was concluded in September 1954. Approximately 170 square miles were mapped, completing a total of eight 7-½ minute quadrangles, or about 400 square miles. Detailed geologic studies were made at the Blue Lizard, Happy Jack, and Fry No. 4 mines, and at the Bell, Maybe, and Scotty claims.

Geologic studies show that the uranium deposits in the White Canyon area occur in channels cut into beds of the Moenkopi formation and filled with conglomerate, sandstone, siltstone, and claystone of the Shinarump conglomerate. A total of 51 channels, ranging from 40 to 600 feet in width and from 4 to 25 feet in depth, have been mapped; 13 of these channels contain at least one uranium deposit having a minimum grade of 0.10 percent U_3O_8, and many others contain low-grade uraniferous material.

Most of the Shinarump-filled channels occur in a belt 8 to 15 miles wide that extends diagonally across the area from Deer Flat on the northeast to beyond the Colorado River on the southwest, a distance of more than 20 miles. The Shinarump conglomerate within this belt generally ranges from 8 to 40 feet in thickness, but locally is absent. Extending outward from this main belt of Shinarump conglomerate are lenses of Shinarump, ranging from 30 to nearly 1,000 feet in width, that trend northwesterly, parrallel roughly to the channels within the belt. Some of these lenses may be the extensions of Shinarump-filled channels within the belt.

Nearly all the significant uranium deposits in the White Canyon area are in channels within and close to the edge of the main belt of Shinarump conglomerate, and are near pinchouts of that formation. Most deposits are localized in beds of sandstone or conglomerate immediately overlying a bed of mudstone or siltstone, and some are in sandstone beds that interfinger with mudstone or siltstone. Mineralized sandstones commonly contain a high percentage of clay cement, and some contain clay pebbles and seams; nearly all contain concentrations of carbonized wood. Concentrations of "trashy" material and perhaps finer-grained fractions of the Shinarump beds appear to occur especially at branches and bends in channels and at deeper scours in the channel floors.

Uraninite commonly occurs in deposits that have been developed behind the oxidized rim outcrops. Most of the uraninite replaces clay seams, clay pebbles, or carbonized wood, and is commonly associated with covellite, bornite, and chalcopyrite.

The following report was transmitted during this report period: TEM-645, "Preliminary report on Happy Jack mine, White Canyon area, San Juan County, Utah," by A. F. Trites, Jr., and R. T. Chew, III.

Capitol Reef area, Utah quadrangle mapping, by J. F. Smith, Jr.

Field work has been completed in the Capitol Reef area; about 910 square miles were mapped. Consolidated rocks in the area range from the Coconino sandstone of Permian age to volcanic rocks of Tertiary age. Chief structural features are the northwest extension of the Waterpocket Fold, the northwest-trending Teasdale anticline, the northwest-trending Teasdale fault, and the north-trending Thousand Lake fault.

Although prospectors have been active in the area, no economically significant uranium deposits have been found. Most exploration has been done in three stratigraphic units: the Moenkopi formation, the Shinarump conglomerate, and the Salt Wash member of the Morrison formation. Uranium in the Moenkopi occurs in a black layer, 1 to 2 inches thick, in a white fine-grained sandstone at the base of a 33-foot-thick pink sandstone; this bed is about 400 feet below the top of the formation. Most deposits in the Shinarump conglomerate occur in thin clay or mixed clay and sandstone beds that fill channels cut into the underlying Moenkopi. In the Salt Wash member the mineralized material is in irregular oblong pockets, generally 3 to 6 feet long and ranging from a few inches to 2 feet thick. Most of the deposits occur in lenses of conglomerate and sandstone at the top of the member. Locally carnotite is disseminated in sandstone or coats pebbles in lenses of conglomerate in the Salt Wash.

The following reports were published in the Guidebook of the Intermountain Association of Petroleum Geologists, 1954: "Geology of the Capitol Reef area, Wayne and Garfield Counties, Utah," by R. G. Luedke; and "Triassic rocks of the San Rafael Swell, Capitol Reef, and adjoining parts of southeastern Utah," by J. H. Stewart and J. F. Smith, Jr. TEM-643, "Preliminary geochemical studies in the Capitol Reef area," by L. C. Huff, was transmitted during this period.

<u>Elk Ridge area, Utah quadrangle mapping, by R. Q. Lewis, Sr.</u>

Mapping was completed in seven 7-½ minute quadrangles. A total of 650 square miles was mapped, 210 square miles remaining to complete the project.

Consolidated sedimentary rocks exposed in the area range in age from Upper Pensylvanian to Jurassic and attain an aggregate thickness of over 4,000 feet. All the known uranium deposits are in rocks of Triassic age.

Small non-economic deposits of uranium occur in the Moenkopi formation and in the lower part of the Chinle formation, and significant deposits occur in the Shinarump conglomerate in the southern part of the area and in the Moss Back member of the Chinle formation in the northern part. The only known deposit in the Chinle formation, other than those in the Moss Back member, is a small deposit in the head of Woodenshoe Canyon, about 2 miles east of Woodenshoe Butte. The deposit is in a silty sandstone ledge about 40 feet above the Shinarump conglomerate and about 80 feet below the base of the Moss Back. The sandstone fills a shallow scour in lower Chinle mudstone. Copper minerals and abnormal radioactivity are restricted to the center of the scour.

In Notch Canyon uranium occurs in blebs and stringers of petroliferous residue in the uppermost sandstone of the Moenkopi about 40 feet below the Shinarump conglomerate. The Shinarump conglomerate is mineralized above this Moenkopi deposit.

In the southern part of the area the Shinarump is present as discontinuous sandstone lenses filling shallow scour channels in the top of the Moenkopi. It is separated from the overlying Moss Back by about 150 feet of lower Chinle mudstone. Northward, the Shinarump pinches out, and the lower Chinle mudstone thins until the Moss Back lies upon the Moenkopi formation. The ore deposits are confined to the lower parts of scour channels cut into the Moenkopi and filled with Shinarump conglomerate or Moss Back sandstone.

The deposits are small, tabular to lenticular in shape, and uranium minerals are disseminated in conglomerate or conglomeratic sandstone immediately above the top contact of the Moenkopi. Hence, any channeling sandstone on top of the Moenkopi is worthy of investigation. Copper minerals such as chalcopyrite, azurite, malachite, and chalcanthite, are usually associated with the uranium and are easier to locate visually than the uranium.

San Rafael Swell area, Utah strip-mapping, by R. C. Robeck

The Moenkopi formation, Shinarump conglomerate, and Chinle formation were studied in the northern part of the Swell (excluding Calf Mesa). A total of 90 linear miles were studied and mapped. All mines and prospects in the Swell were visited to determine their stratigraphic position and ore potential.

In this area, the Shinarump is represented by lenses of Shinarump-type quartzose sandstone within, below, and above the siltstones and mudstones of the "purple-white" band described by Finch (TEI-328, p. 30). In the area of detailed study four separate Shinarump river-channel systems with a northwesterly trend were found. A total of 73 exposures of Shinarump channels were studied. Of these, 23 are radioactive, but only 2 or 3 are of possible ore grade at the outcrop. The Shinarump, in the form of the "purple-white" band, is present throughout the area mapped except for one mile on the east flank of the Swell where pre-Moss Back erosion has removed it. The maximum measured thickness of Shinarump channel sediments is 101 feet, and the average thickness of the entire Shinarump studied is about 25 feet. The Shinarump channel sediments normally average about 25 percent sand and about 75 percent finer-grained clastics.

The Moss Back member of the Chinle lies directly on the Shinarump in the northern part of the Swell. Of the numerous radioactive localities in the Moss Back member, some along the northwestern side of the Swell probably warrant additional prospecting. A pink coarse-grained arkosic sandstone near the top of the Moenkopi shows no radioactivity. Sandstones in the Church Rock member of the Chinle formation were found to be slightly radioactive in two places and will be studied further. The Coconino sandstone was checked for radioactivity in a 700-foot section in the Black Box of the San Rafael River with negative results.

Lisbon Valley area, Utah-Colo. quadrangle mapping, by G. W. Weir

During the 1954 field season the Jurassic rocks of the south-central part of the area, Dry Valley and East Canyon, were mapped on aerial photographs. A geologic reconnaissance was made of the unmapped part of the area and most of the significant ore deposits were examined.

The larger uranium deposits in the Salt Wash member of the Morrison formation lie in a narrow belt in which the ore-bearing ledge of the Salt Wash is relatively thick and persistent. The belt has a northeasterly trend and includes the Frisco group on the west side of the canyon and the Sunset, Profit No. 1, and Black Bottom mines on the east. The belt may extend southwesterly as far as the Happy Jack mine on U. S. highway 160 and possibly farther into the Abajo Mountains area. Away from the belt the ore-bearing ledge is generally thin and discontinuous and the ore deposits, though numerous, are small. Exposures of Salt Wash are poor along the south rim of Dry Valley but the Waterfall group and Wilson mine are believed to lie in a similar belt of relatively favorable ground that trends southeasterly. These two hypothetical belts may intersect beneath the north edge of the Sage Plain.

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Reconnaissance study of the Moss Back member, the lower ore-bearing part of the Chinle formation of Big Indian Wash and Lisbon Valley, suggests that the Moss Back probably pinches out along the axis of the Lisbon Valley anticline and may not be found north of Lisbon Valley. A quartzose conglomeratic lower Chinle unit crops out poorly in Lackey Basin and around the south and west flanks of South Mountain, the southernmost part of the La Sal Mountains laccolithic group. Although this lower Chinle differs from the ore-bearing Moss Back member of the Chinle of Big Indian Wash, it resembles the ore-bearing basal Chinle north of Moab, Utah. The Chinle of South Mountain is accessible with difficulty and relatively unprospected, and requires further study to assess its uranium potential.

The Lisbon Valley area contains many copper deposits, particularly in the Dakota sandstone and Burro Canyon formation. Small amounts of copper also occur in the Cutler, Kayenta, and Morrison formations. One deposit, the Lucky Strike prospect in eastern Lisbon Valley near the Colorado line, shows anomalous radioactivity. Here the green vanadium-copper mineral volborthite, a yellow uranium mineral probably of the carnotite group, and an unidentified black uranium mineral, possibly pitchblende, are associated with the dominant copper minerals, malachite, azurite, and chalcocite. The deposit occurs in the Burro Canyon (?) formation in a fault zone along which the Burro Canyon (?) is faulted against the Morrison formation. The stratigraphic throw on the fault is estimated to be about 450 feet. The Lucky Strike prospect suggests that the copper deposits and the uranium deposits of the Lisbon Valley area may be closely related.

Moab-Inter-river area, Utah strip-mapping, by E. N. Hinrichs

The Moab area lies south of Moab, east of the Colorado River, north of the 38th parallel, and roughly west of U. S. highway 160. The Inter-river area is the area between the Green and Colorado Rivers south of 38 degrees 45 minutes north latitude.

During the 1954 field season, about 108 linear miles of the 245 linear miles of Triassic rocks in the Moab area were mapped. All accessible exposures of Moenkopi and of a sandstone at the base of the Chinle (tentatively identified as the Moss Back member) that appeared favorable for uranium deposits were examined with scintillation counters. The following geologic features are considered favorable: northwest-trending faults across anticlines and domes; channels in siltstone or claystone filled with conglomerate, sandstone, or arkose; large bleached areas; large amounts of organic matter; unusually thick sections of basal Chinle sandstone; and copper minerals.

The known uranium deposits in this area can be classified into two groups based on the most obvious controls of the ore: (1) deposits along northwest-trending faults on anticlines or domes, and (2) deposits not apparently related to major tectonic structures but occurring in channels cut in siltstone and claystone and filled with conglomerate, sandstone, or arkose.

Examples of deposits of the first type are in the Rico, Cutler, and Chinle formations in the canyon of lower Cane Creek where about six high-angle faults trending N 42° W and spaced 10 to 50 feet apart cut the north flank of the Cane Creek anticline. Uranium deposits found along these faults early in 1954 are being mined. They are in fault gouge and in brecciated sandstone and arkose along and between the faults. Uranium minerals coat fractures and carbonaceous material. Many uranium, vanadium, and copper minerals have been collected and have been submitted for identification. The following minerals were identified from field examination of hand specimens: andersonite or schroeckingerite, tyuyamunite, zippeite?, chalcocite, malachite, and brochantite?. The ratio of uranium to vanadium in the ore produced is 1:2.

A deposit of the second type is in the Moss Back member of the Chinle formation between Cane Creek and Lockhart Canyon. The uranium ore occurs in conglomeratic parts of a sandstone layer, one-half to one and one-half feet thick, at the base of the Moss Back and on the flank of a small channel. The channel trends about N 45° W. The following minerals have been identified tentatively in the field: pitchblende, schroeckingerite, chalcopyrite, and pyrite. Quartz granules within 3 inches of the ore are smoky black. The ratio of uranium to vanadium is 3:1.

Although no radioactivity was detected at the surface, parts of the faulted Cane Creek anticline between Hurrah Pass and the Colorado River appear to be favorable for the occurrence of uranium deposits. Faulted parts of other anticlines and domes in the area also appear to be favorable. In much of the area the Moss Back member of the Chinle crops out as a ledge about midway on a very steep slope as much as 800 feet high, but in the southern part of the area along tributaries to Indian Creek it forms broad benches that afford good sites for exploratory drilling.

Circle Cliffs area, Utah quadrangle mapping, by E. S. Davidson

The Circle Cliffs area, comprising twelve 7-½ minute quadrangles, is in Garfield and Kane Counties, Utah, adjacent to the Capitol Reef area to the north and the Henry Mountains to the east. Detailed quadrangle and mine mapping was carried on from the middle of July to November, during which time about one-sixth of the area was mapped.

The principal structural feature is the doubly pitching asymmetric Circle Cliffs anticline, the steep eastern side of which forms part of the Waterpocket Fold. No major faults occur but several minor faults are present in the interior of the area. The rocks in the center of the Circle Cliffs anticline have been deeply eroded, leaving massive Wingate and Navajo sandstone cliffs rimming an oval area about 30 miles long and 10 miles wide in which the principal rock unit is the Moenkopi formation of Triassic age. Permian beds underlying the Moenkopi formation are exposed in a few canyons. Of possible stratigraphic significance is the discovery of prominent and continuous outcrops of a mottled red and white very fine-grained sandstone and siltstone with sparse medium and coarse quartz grains, unconformably overlying the Moenkopi formation and unconformably underlying typical Shinarump conglomerate. This unit may represent an early Shinarump drainage system but to date no radioactive anomalies have been noted in it.

Uraniferous material has been found in the Moenkopi formation, the Shinarump conglomerate, and the Chinle formation within the Circle Cliffs proper and in the Salt Wash member of the Morrison formation along the east margin of the Circle Cliffs anticline. Recent mining has been confined to deposits in slightly slumped and fractured Moenkopi shale on the banks of channels filled with Shinarump sandstone and conglomerate. Uranium minerals noted in essentially unoxidized ore bodies are uraninite and becquerelite, associated with copper and iron sulfides. Meta-autunite, metazeunerite, metatorbernite, and schroeckingerite are found on the outcrop and in the weathered parts of the deposits, commonly associated with jarosite and copper carbonates. Vanadiferous radioactive material has been found in the Salt Wash member of the Morrison formation, and a yellow radioactive mineral resembling carnotite coats quartz grains and fractures in silicified logs in the Chinle formation.

Abajo Mountains area, Utah quadrangle mapping, by I. J. Witkind

During the field season of 1954 about 25 square miles were mapped in the northeast corner of the Abajo Mountains. Exposed consolidated sedimentary strata range in age from Triassic to Cretaceous and have a combined thickness of about 3,400 feet. Most of the strata dip away from the Abajo Mountains. Locally, however, small structures interrupt the even dip of the beds. Faulting is not common.

The laccoliths of the Abajo Mountains igneous complex are composed chiefly of diorite porphyry. About 11 mines, active at the turn of the century as producers of gold and silver, were developed either in igneous rock or at contacts of the sediments with the igneous rocks. Abnormal radioactivity was not noted near the mines.

The uranium-vanadium deposits in the Abajo Mountains area are in the Salt Wash member of the Morrison and appear to be localized in a zone about 4 miles wide that trends in a N 80° E direction through the northeastern part of the area. This zone includes the southern end of Shay Mountain, the northern end of Robertson Pasture, and the head of Hart's Draw. A prolongation of this zone to the northeast intercepts other mines and favorable ground in the Salt Wash near Lisbon Valley, Utah.

Uranium-vanadium minerals are localized in several sandstone beds of the Salt Wash member of the Morrison formation. These beds are about 150 feet above the base of the Salt Wash and contain two types of uranium-vanadium ore bodies. Of these the most common consists of small crudely oval, discrete, pod-like bodies marked by irregular protuberances. They range in size from 25 feet long, 3 feet thick, and 10 to 12 feet wide to small nodular masses about 3 feet in diameter. These small ore bodies are irregularly distributed both vertically and laterally throughout the ore-bearing sandstone. In a few localities they form clusters that are generally about 5 feet thick, 200 feet wide, and 50 feet long. Individual ore bodies in the clusters are connected by mineralized seams of rock ranging in thickness from 1 inch to 6 inches. These mineralized seams apparently contain vanadium but little or no uranium.

Ore bodies of the second type are flat tabular masses commonly 20 to 40 feet wide, 2 to 4 feet thick, and 200 to 300 feet long. They are not common and, where exposed in mine workings, thicken and thin erratically. The ore commonly occurs along bedding planes of the host rock although locally it cuts across the bedding along a remarkably smooth interface between mineralized and unmineralized strata. The upper and lower edges of these tabular bodies also form sharp boundaries with enclosing strata. The richest ore appears to be localized near the center of the bodies, although this may not be a general rule. The uranium-vanadium ratio is about 1:10 in ore bodies of both types.

Sage Plain area, Utah-Colo. quadrangle mapping, by L. C. Huff

During July 1954, when the Sage Plain project began, most of the uranium-vanadium deposits of the area were studied. During August and September geologic study and mapping was completed in approximately four of the total of fifteen 7-½ minute quadrangles.

Geologic formations exposed in this area are flat-lying and range from the Navajo sandstone of Jurassic age to the Mancos shale of Upper Cretaceous age. Pediment gravels and loess of probably early Pleistocene age were recognized and mapped near Monticello.

There are many scattered uranium-vanadium deposits in the Salt Wash member of the Morrison formation within this area. The Salt Wash member is composed of massive, cross-bedded sandstones alternating with maroon and gray mudstones. The ore is commonly localized in one or more ledges of the sandstone in the upper part of the Salt Wash member. The ore minerals impregnate the sandstone near accumulations of carbonaceous plant fossils. Ore bodies are generally not more than three or four feet thick. Accumulations of plant fossils, thickness of the ore sandstone, channeling of the ore sand, and gray or altered mudstone serve as ore guides. Some of the uranium-vanadium deposits of the Sage Plain area are being mined and prospecting within the area is active. The aggregate production of the area, however, is small.

Western San Juan Mountains area, Colo. quadrangle mapping, by A. L. Bush

Areal geologic mapping of the Placerville, Little Cone, Grayhead, Dolores Peaks SE, and Mt. Wilson 7-½ minute quadrangles, San Miguel and Dolores Counties, Colo., was continued during the reporting period. In the Placerville area, an essentially continuous vanadium layer in the Entrada sandstone contains small but significant amounts of uranium. The proximity of these deposits to the intrusive and extrusive rocks and hydrothermal vein systems of the western part of the San Juan Mountains makes possible a detailed study of the relationship of uranium-vanadium mineralization to base- and precious-metal mineralization.

Geologic mapping was completed for an area of about 50 square miles during the 1954 field season. Geologic mapping of the Placerville quadrangle is essentially completed.

The northern half of the district is characterized by a series of gentle anticlines and synclines whose trend and plunge are commonly to the northwest. In general these structures seem to be related to stresses that preceded the domal uplift of the San Juan volcanic pile. Superimposed on these structures is a conjugate system of closely-spaced, dominantly normal faults. These faults are well developed in the northern third of the district and appear to be related to large-scale domal uplift, but locally they are related to the emplacement of small, stock-like bodies of diorite and diorite-monzonite. The faults, where observed, displace the vanadium-uranium layer. The results of a small amount of recent mining and drilling suggest that little if any direct relationship exists between the faults and the present location of the uranium and vanadium. The results suggest, however, that the uranium tends to be concentrated near the margins of thick parts of the vanadium-uranium layer.

The San Miguel Mountains, near the center of the district, have cores of stock-like bodies of dioritic rock. The Cretaceous and Tertiary sedimentary and volcanic rocks in general dip toward the stocks, but detailed contact relationships have not as yet been determined. South of the San Miguel Mountains, the upper Paleozoic and Mesozoic sediments rise smoothly over the dome of the Rico Mountains, a laccolithic complex. In general, faults appear to be rare in the area between the San Miguel and the Rico Mountains.

Photogeologic mapping
by W. A. Fischer

The photogeologic mapping program is designed to provide regional geologic maps of specified areas in Utah and Arizona to serve until more detailed surveys can be made.

Photogeologic maps of fifty-seven $7\frac{1}{2}$-minute quadrangles have been completed since June 1, 1954. The total number completed since the beginning of the work in the winter of 1951-52 is 241, of which 182 are now available for public inspection. It is estimated that more than 25,000 copies of the maps have been distributed to the public during that period.

Since June 1, 1954 maps of fifty-eight $7\frac{1}{2}$-minute quadrangles have been submitted for publication in the Geological Survey's Miscellaneous Geologic Investigations series. Publication in this series is expected to make the maps available more readily to the public at a lower cost.

A change in the method of preparing photogeologic maps, involving the use of high-altitude photography and the Kelsh plotter, is now being made. It is anticipated that the new procedure will result in maps of better quality as well as a higher production rate.

The progress of the photogeologic mapping program is shown on the index map, figure 2. The areas shown on the map as "scheduled for production" are expected to be completed in fiscal year 1956.

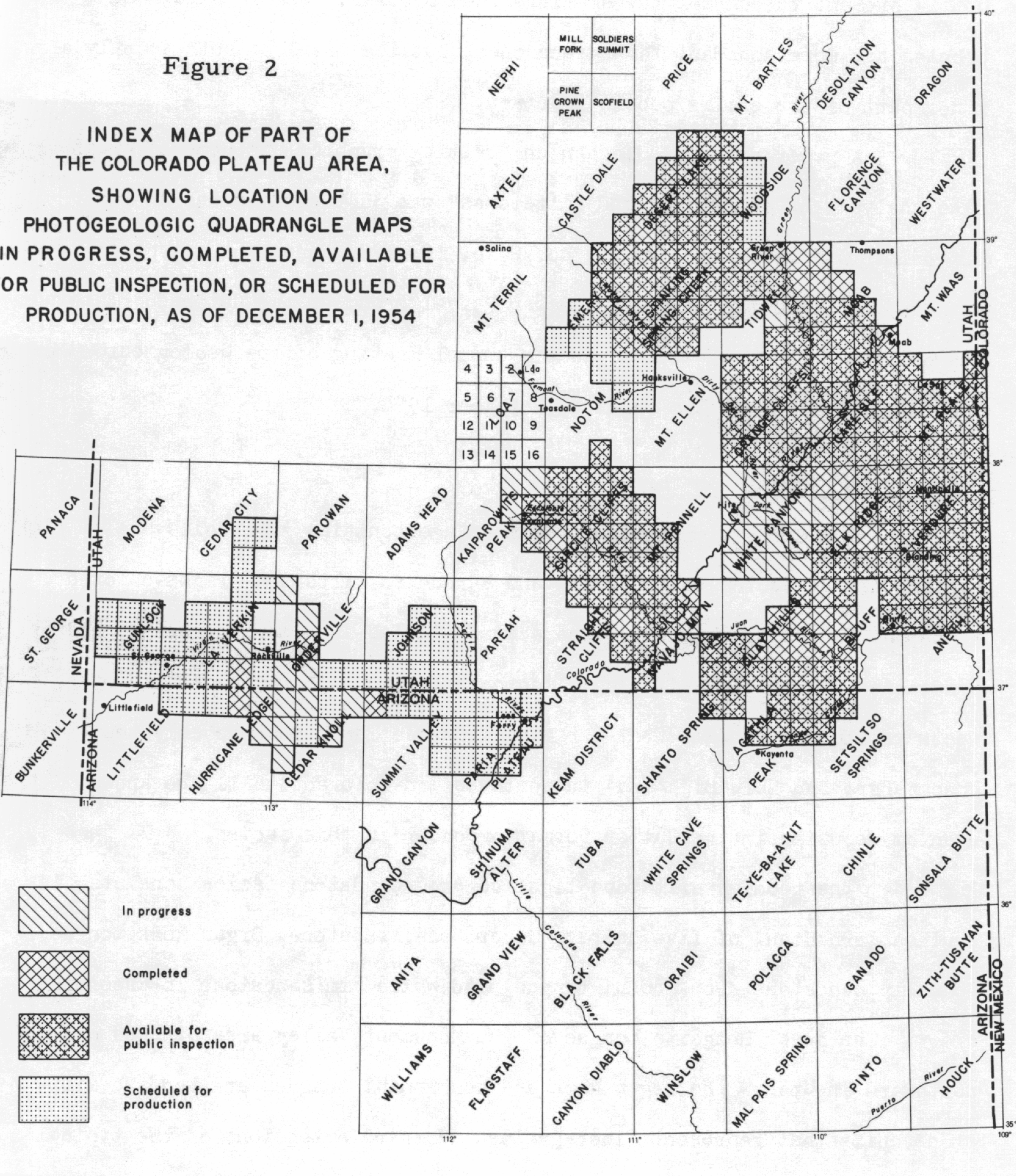
Stratigraphic studies
by G. A. Williams

Morrison formation

Field studies of the Morrison formation have been completed except for spot checking of critical areas. The sedimentary petrology laboratory has completed analysis of samples collected in the Morrison program. Field studies are in progress to compare the pebble assemblage of the Salt Wash member of the Morrison formation with that of the Brushy Basin member of the Morrison formation. The conglomerate of the Brushy Basin contains red and green chert pebbles and granules. Incomplete study of these colors shows that

Figure 2

INDEX MAP OF PART OF THE COLORADO PLATEAU AREA, SHOWING LOCATION OF PHOTOGEOLOGIC QUADRANGLE MAPS IN PROGRESS, COMPLETED, AVAILABLE FOR PUBLIC INSPECTION, OR SCHEDULED FOR PRODUCTION, AS OF DECEMBER 1, 1954



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the green may be only surficial on the relatively large pebble fragments, but is present throughout the smaller-sized pebbles. Red granules and pebbles are more abundant than green ones, but the total of both is only a minor part of the entire pebble fraction.

A paper by R. A. Cadigan on "Testing graphical methods of grain-size analysis of sandstones and siltstones" was published in the Journal of Sedimentary Petrology, v. 24, no. 2, p. 123-127, June 1954. A paper entitled "Correlative units in the San Rafael group on the Colorado Plateau" was presented by R. A. Cadigan at the annual meeting of the Geological Society of America at Los Angeles, November 1954.

Triassic and associated formations

The Cutler formation of Permian age contains two facies: a typical arkose facies to the east, and a reddish siltstone--light-colored sandstone facies to the west. The eastern facies is a medium-grained red sandstone that is classified as a tectonic arkose. It was deposited by westward flowing streams from a rising granitic landmass (probably the Uncompahgre-San Luis highland) in southwestern Colorado. All the known uranium deposits in the Cutler formation occur in this facies.

The reddish siltstone-light colored sandstone facies consists, in southeastern Utah, of five units: Cedar Mesa sandstone, Organ Rock tongue, DeChelly sandstone, Hoskinnini tongue, and White Rim sandstone in ascending order. The basal Halgaito tongue of the Monument Valley area pinches out northward in Utah. The Organ Rock and Hoskinnini tongues are reddish siltstone units that represent finer-grained westward extensions of the typical arkose facies. The Organ Rock tongue consists of siltstone and very fine-grained silty sandstone that is classified in part as graywacke and in part as arkose. The Hoskinnini tongue is present in much of southeastern Utah and adjoining parts of Colorado, as well as in the Monument Valley region. It consists of siltstone and very fine-grained sandstone that contains coarser sand grains and is classified as an arkose. The combination of coarse grains in a finer-grained matrix and discontinuous wavy laminae differentiate the Hoskinnini tongue from the underlying and overlying units and afford the basis for correlating the Hoskinnini with rocks not previously identified as Hoskinnini in southeastern Utah and southwestern Colorado. The thickness of the Hoskinnini ranges from 50 to 200 feet; pinchouts on the west are abrupt. Intraformational and chert pebble conglomerates, contorted stratification, and petroliferous material are present near some of these pinchouts.

Although the Hoskinnini is currently assigned to the Cutler formation, detailed studies show the Hoskinnini to differ from typical Cutler rocks and to be closely related to the Moenkopi formation of Early and Middle (?) Triassic age.

The Cedar Mesa, DeChelly, and White Rim sandstone members of the Cutler formation are the light-colored sandstone units of the red siltstone-light colored sandstone facies. The Cedar Mesa sandstone member is a very fine-grained feldspathic orthoquartzite. The DeChelly sandstone is a very fine-grained tuffaceous feldspathic orthoquartzite. Classification of the White Rim member is not yet clear, but its origin and source were probably similar to those of the DeChelly sandstone.

The Moenkopi formation is predominantly a red siltstone that contains beds of very fine-grained sandstone. The whole unit is classified as a feldspathic orthoquartzite; minor amounts of siltstone are classified as arkose. The Sinbad limestone member crops out in central and south-central Utah and to the south overlaps the underlying part of the Moenkopi.

The typical sandstone of the Shinarump conglomerate of Late Triassic age is a fine-grained feldspathic orthoquartzite with variations ranging from tuffaceous feldspathic orthoquartzite to arkose. The sources may have been rising highlands of granitic composition, containing active continental-type volcanoes.

The Chinle formation of Late Triassic age is now divided into several members which are to be named and defined by the USGS in forthcoming reports. In ascending order, these members are tentatively named the Monitor Butte, Moss Back, Petrified Forest, Owl Rock, and Church Rock. The composition of the sandstone and coarse siltstone of the Monitor Butte member ranges from tuffaceous feldspathic orthoquartzite to arkose.

The Moss Back member is composed of yellowish gray and very pale orange, fine- to medium-grained sandstone; a few lenses of siltstone; and conglomerate containing pebbles of siltstone, limestone, quartzite, quartz, and chert. Carbonaceous and silicified plant materials are commonly present. The Moss Back ranges from 50 to 125 feet in thickness. It can be differentiated lithologically from the Shinarump conglomerate by the presence of many siltstone and limestone pebbles and abundant quartzite pebbles in the Moss Back. Texturally similar sandstone units in the underlying part of the Chinle can be differentiated lithologically from the Moss Back by their lack of quartz and quartzite pebbles. The lower and upper contacts of the Moss Back are generally placed at the sharp break between the cross-stratified sandstone of the Moss Back and the greenish or reddish siltstone or claystone of the underlying and overlying parts of the Chinle. Locally small channels that cut into the underlying strata are present. The Moss Back sandstone has been correlated over much of southeastern Utah and is tentatively correlated with beds in extreme eastern Utah and southwestern Colorado.

It covers an area about 50 miles wide and 155 miles long. The Moss Back is a fluvial deposit formed by a network of braided streams that flowed northwest on a smooth gently sloping plain.

The sandstone and siltstone units of the Petrified Forest member of the Chinle formation are orthoquartzite tuffs. Relatively large thicknesses of bentonitic claystone and siltstone characterize these units. In contrast to the other members, the Owl Rock member contains limestone and limey siltstone as well as detrital units of tuffaceous arkose. The Church Rock member has two components, arkose and graywacke.

The Glen Canyon group consists of the Wingate sandstone (Triassic), the Kayenta formation (Jurassic?), and the Navajo sandstone (Jurassic). The Wingate ranges in composition from tuffaceous arkose to feldspathic orthoquartzite. It is interpreted to be an eolian deposit that was deposited by winds blowing from the northwest. The Kayenta is generally a feldspathic orthoquartzite, but contains some beds of arkose. It appears to have been deposited by streams that flowed to the west or southwest. The Navajo sandstone is a feldspathic orthoquartzite. It is inferred to be an eolian deposit formed by winds blowing from the northwest.

Many determinations have been made of the type of clays in the sandstones of the Triassic formations. Evidence to date supports the hypothesis that much of the hydromica in the Shinarump and Chinle is the result of the alteration of montmorillonite in the presence of soluble potassium salts.

In a microscopic study of the composition of ore-bearing sandstones and barren sandstones in the Shinarump conglomerate and Moss Back member of the Chinle formation, ore-bearing sandstones were found to contain 20 to 35 percent kaolin or interstitial ore minerals apparently replacing kaolin. Barren sandstones away from known ore deposits usually contain

10 percent or less of kaolin. On the basis of this comparison sandstone strata containing 15 to 35 percent kaolin seem to be more favorable for the occurrence of uranium deposits than strata containing less than 15 percent kaolin. The possible influence of kaolin on the deposition of ore minerals may be physical, chemical, or both.

Ground-water studies
by D. A. Jobin

The minimum sampling density necessary to measure regional differences in transmissivity of the rocks of the Colorado Plateau was reappraised, and most of the additional samples considered necessary have been collected. A general report, the preliminary appraisal of the transmissivity of the sedimentary rocks of the Colorado Plateau, has been prepared. Conclusions are summarized below:

1. Although uranium-bearing sediments are widespread and diverse in character, the major production is from sediments having the same transmissive characteristics.

2. These sediments have a high mean permeability and are characterized by large variations in permeability.

3. These sediments are only fair to poor in regional transmissive capacity and are characterized by large variations in local transmissivity.

Little permeability data are presently available from northwestern New Mexico and northern Arizona. This area will be sampled and laboratory measurements will be completed during the next period. A complete compilation and analysis of all data will then be made.

Botanical studies

Botanical research, by H. L. Cannon

Reconnaissance studies.--The deposits at Myton, Utah appear to have no botanical relations of interest and no plans for further work in the area have been made. Geochemical as well as botanical relations at Poison Buttes, Wyoming can probably be used for prospecting. Further work on uncommon species of indicator plants and related geochemical studies are planned for next spring. *Astragalus pattersoni* is indicative of mineralized ground in both the Sanastee and Pojoaque areas of New Mexico. Tests indicate that several other *Astragalus* species not known to be selenium absorbers are indicative of beds of lower radicactivity. Studies of the low grade *Astragalus* species from these localities as well as species which occur at higher altitudes are in progress.

Laboratory studies.--Information on selenium distribution in the ore and surrounding barren rock of ten carefully sampled ore bodies in the Salt Wash member of the Morrison formation as well as paired ore and barren rock samples from other Jurassic and Triassic rocks of the Colorado Plateau are being compiled and studied statistically. The correlation between seleniferous beds and uranium mineralization is marked.

Perennial indicator plants planted in 1953 were grown to maturity in plot experiments near Santa Fe, New Mexico. The results will aid in understanding plant distribution in uranium districts. For instance, *Stadeya pinnata* matured in both sodium selenite and gypsum plots but could not be grown in carnotite nor in the control. *Astragalus pattersoni* on the other hand, matured in sodium selenite and also carnotite and favored a combination of the two. *Grindelia*, suspected of being a selenium indicator, matured in all plots, but was stunted by selenium and encouraged to unusual and much increased growth by the addition of carnotite. Mentzelia matured only in carnotite plots. These growth differences are of prime importance in prospecting.

A cooperative agreement with the Cornell Experiment Station will make continuation of these preliminary studies under controlled conditions possible. Pilot experiments in which five species of desert plants will be grown in nutrient solution containing U, V, Se, Ca, Na, P, and K are under way to determine tolerance and growth habits under greenhouse conditions. A more elaborate experiment in which plants will be grown in 200 combinations of the above elements will be set up in the spring.

Botanical prospecting, by F. J. Kleinhampl and P. F. Narten

In some areas, ground favorable for uranium deposits can be delimited by either or both of two botanical methods. The indicator plant method utilizes the fact that certain plant species require high soil concentrations of selenium or sulfur. Where these elements are associated with uranium deposits, the detailed mapping of the distribution of such selenium or sulfur indicator plants may outline favorable ground. The absorber plant method, based on the comparative amounts of uranium found in the ash of plant tissue, is used by systematically sampling plants on benches or rims where the rocks are thought to contain uranium at depths as much as 40 feet. One or more parts per million uranium in plant ash of special types of trees is considered anomalous.

During the report period botanical prospecting field parties worked in the Grants district, Valencia and McKinley Counties, N. Mex.; Elk Ridge, San Juan County, Utah; San Rafael Swell, Emery County, Utah; and Circle

Cliffs area, Garfield County, Utah. Locations of these projects are shown in figure 3.

Two reports covering work completed during previous report periods were transmitted: TEM-789, "A botanical reconnaissance for uranium near Trachyte Ranch, Garfield County, Utah," by P. F. Narten and E. C. Clebsch; and TEI-422, "Methods of botanical prospecting for uranium deposits on the Colorado Plateau," by H. L. Cannon.

Results from each field project are summarized below.

Grants district.--A study was made in the Grants district to determine the usefulness of selenium-indicator plants as a guide to ore deposits in the sandstone of the Morrison formation and Dakota sandstone between Grants and Gallup, N. Mex. Earlier work in the Poison Canyon area established a direct correlation between indicator plants and mineralized sandstone. The distribution of indicator plants was mapped near known deposits and in other parts of the area considered geologically favorable for ore.

Selenium-requiring plants were found in the vicinity of deposits that contain uranium dominantly in the low-valent state; these plants were not observed near deposits that contain uranium dominantly in the high-valent state. *Astragalus pattersoni* was found to be generally the most useful plant for indicating uraniferous ground, being more nearly restricted to the vicinity of deposits. *A. confertiflorus*, which requires less selenium than *A. pattersoni* for normal growth, is more widespread. *A. confertiflorus* and very locally *Stanleya pinnata*, which also requires less selenium than *A. patteroni*, probably can be used only to define broad areas of favorable ground. The overall distribution of these plants suggests that most of the

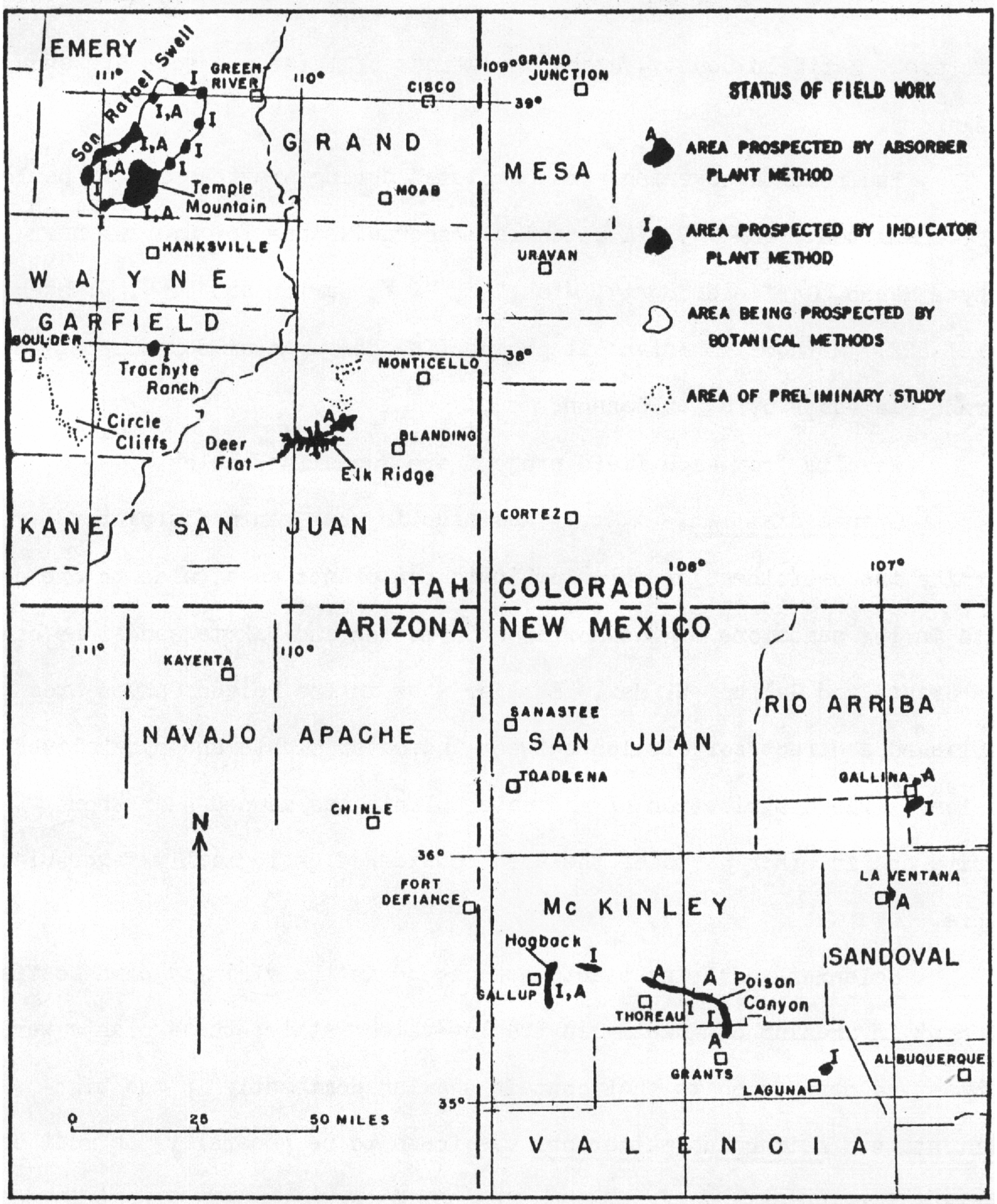


Figure 3.--INDEX MAP OF PART OF THE COLORADO PLATEAU SHOWING LOCATION OF BOTANICAL PROSPECTING PROJECTS, 1952-1955

selenium in the sandstone of the Grants district is associated with low-valent uranium minerals; it is not, however, entirely restricted to such minerals, but occurs in small concentrations away from uranium deposits.

Elk Ridge.--About 18 linear miles of Shinarump conglomerate and basal Chinle beds cropping out along Elk Ridge, San Juan County, Utah, were prospected by the absorber plant method. Preliminary results indicate a number of botanical anomalies that suggest the presence of mineralized ground.

Deer Flat.--More than 27 linear miles of Shinarump conglomerate and basal Chinle beds cropping out in the Deer Flat area, San Juan County, Utah, were prospected by the absorber plant method. Botanical anomalies were detected over all major known deposits in the area as well as in unexplored areas where no deposits are known. The distribution, quantity, and quality of these anomalies indicate that the southern half of the Deer Flat area is more favorable for concealed uranium deposits than the northern half. None of the anomalies indicated by the absorber plants has been explored by drilling.

San Rafael Swell.--Both absorber and indicator plant methods of botanical prospecting were tested in the San Rafael Swell area, Emery County, Utah. Trees growing 30 to 80 feet above known uranium deposits on benches of the Moss Back member of the Chinle formation were sampled and analyzed. Results indicate that this method is not useful in this area where the ore horizon lies at depths of 40 feet or more.

Circle Cliffs area.--The indicator plant method of prospecting was used in the Circle Cliffs area, Garfield County, Utah, to determine whether it could effectively locate favorable ground along the ore zone adjacent to the mid-Triassic unconformity. Primary indicator plants (TEI-422) do not appear to be associated with ore in this zone. However, these primary indicators are clustered along the Salt Wash member of the Morrison formation (Jurassic) where it crops out in the Waterpocket Fold, and occur near one mine in the Salt Wash. The indicators may thus prove useful in searching for uranium deposits in the Salt Wash in areas adjacent to the Circle Cliffs.

Mineralogic studies

General mineralogic studies, by Theodore Botinelly and Alice Weeks

Ore minerals.--In seven weeks of field work, emphasis was placed on study of the paragenesis of the Plateau deposits, the pH conditions during oxidation, the relation of the stage of oxidation to depth and to water table, and the thickness of the transition zone between unoxidized and oxidized ore. The field evidence is consistent with the idea that the oxidized ore was derived from the unoxidized ore in very recent time as the water table was lowered. Pyrite and calcite are removed and iron oxides and gypsum are formed during oxidation, thereby causing considerable change in the cementing material and the permeability of the rocks.

Mineralogic and paragenetic studies of the Jo Dandy area are in mid-stage and only general results can be presented. The mineralogy of the ore is rather simple; low valence black uranium and vanadium minerals such as montroseite and "coffinite" make up most of the ore now being mined. Corvusite, vanadium silicates, carnotite and tyuyamunite make up the oxidized parts of the ores. Gangue minerals other than the quartz and clay of the host rocks are pyrite, marcasite, barite, calcite, and gypsum. Sphalerite and galena are rare but were found associated with pyrite.

Traces of native selenium and of rare vanadates occurring in the mines of the Bull Canyon district were also found. The mineralogy is apparently typical of a vanadium-uranium ore body.

Only general paragenetic relations have been established. The low valence minerals replace host rock and organic materials sometimes with extreme fidelity. High valence minerals replace the low valence minerals; the sequence conforms to the oxidation sequence proposed by Garrels and Weeks.

The study is at present concentrated on the relation of the primary vanadium minerals to the primary uranium minerals. Textural relations that have been observed are indeterminate and no relative age can be given. From the textures observed the best guess at present is that the low valence uranium and vanadium minerals are contemporaneous. Pyrite seems to be of two origins; some is associated with the ore and some was formed probably during diagenesis of the sediments. Gypsum is in part in cements that were replaced by ore minerals and in part in veins cutting ore. Because gypsum is so readily soluble it might be expected to move rather extensively. Quartz grains in the sandstones show signs of corrosion and replacement by vanadium-uranium minerals. Barite tentatively is late replacing ore minerals, but the textures are not diagnostic.

Preliminary study of polished sections of mineralized carbonaceous materials indicates that mineralized wood is more abundant than previously thought and that several specimens of so-called asphaltite are in fact coalified wood.

Study of the fine-grained, vanadium-bearing silicate minerals interstitial in ore sandstones indicates the presence of at least three minerals: chlorite, roscoelite, and vanadium hydromica. The least oxidized ore at Rifle, Colorado (sample collected by R. P. Fischer) contains microscopic crystals of montroseite around the quartz grains.

New data on problem minerals include a chemical analysis of corvusite from Monument No. 2 mine, Arizona, and a chemical analysis of synthetic volborthite.

Data on new minerals include the finding of single crystals of "doloresite", a new V^{+4} mineral. Additional specimens of sodium vanadate from Utah yielded sufficient material to complete the work on this mineral. An iron vanadyl vanadate, first found in the Hummer mine in 1950, was found in ore from the North Star and from the Peanut mines in Colorado. A new calcium hypovanadate from the Peanut mine was analyzed; it is also known from the Sundown claim in the Slick Rock district, Colorado. Crystallographic study was begun on two additional new vanadium minerals from the Peanut mine.

Chemical and spectrographic determinations were completed on purified pyrite and marcasite samples from various localities in the Colorado Plateau. The Co/Ni ratio is quite variable and the cobalt content is more variable than the nickel content. Selenium is concentrated more in marcasite than in pyrite.

A microdrill, designed and fabricated at the Washington Trace Elements laboratory, proved satisfactory for obtaining small pure fractions of minerals from polished sections. The microdrill was adapted for use with the ore-microscope at about 100X magnification.

The collection of uranium and vanadium minerals was exhibited at the GSA meeting in Los Angeles November 1-3, 1954.

More than 3000 copies of Bulletin 1009-B, "Identification and occurrence of uranium and vanadium minerals from the Colorado Plateaus," were sold in the first two months after it was published and the bulletin was reprinted in August.

TEI-454, "Abernathyite, a new uranium mineral of the metatorbernite group," by M. E. Thompson, Blanche Ingram, and E. B. Gross was issued.

Clay minerals.--Work on the clay mineral studies of the Triassic formations has been confined to field observations and sampling for laboratory work. The Triassic outcrops of southeastern Utah and nearby areas in Colorado and Arizona were sampled at approximately 20-mile intervals with an average of 10 samples from each section. The objective of the work is to determine the regional and stratigraphic distribution of the clay minerals of the Triassic formations for comparison with the clays closely associated with uranium ores.

As there is no published account of an investigation of such a large mass of rock, there is no precedent for the best sampling technique for the present study. What stratigraphic and geographic interval of sampling is necessary to characterize the clay mineral distribution? Should the samples be collected statistically at pre-determined intervals, or should they be collected to represent the various rock types in a section regardless of their stratigraphic position? A compromise between the two extremes was adopted. Generally speaking, the samples were taken at fairly even stratigraphic intervals with emphasis on the rocks most closely associated with the uranium-bearing Shinarump and Moss Back sandstones. However, numerous deviations from this sampling procedure are made to determine how the sampling technique might be improved.

Results from the samples collected this year should indicate what additional sampling is necessary in southeastern Utah and how further work in areas outside those already sampled might most profitably be conducted.

Distribution of elements, by E. M. Shoemaker

The frequency distribution of most elements in barren sandstones, including both major and minor elements, has been found to be log-normal. Establishment of this fact has permitted the use of Fisher's t estimator to to estimate the most probable arithmetic mean composition of barren Salt Wash sandstone. Because of the log-normal habit of the elements and because log standard deviations of the individual elements are closely comparable it is also possible to estimate with fair accuracy the mean composition for elements whose mean lies slightly below the threshold of detection by the spectrographic method. A comparison of average Salt Wash sandstone with the average for sandstone published by Rankama and Sahama is given in table 1.

Study of the regional variation in minor-element content in the barren Salt Wash sandstone indicates a distinct regional high in copper centered roughly on the Slick Rock district, San Miguel and Dolores Counties, Colo. (fig. 4). Vanadium content of barren Salt Wash sandstone is distinctly high over an area that roughly covers the Uravan mineral belt (fig. 5).

Comparisons were made between the computed average compositions of formations ranging from the Cutler formation of Permian age to the Dakota sandstone of Late Cretaceous age, and the number of known uranium deposits per unit volumes of sandstone for each of these formations. Potassium was found to have a significant negative correlation with the number of known uranium deposits per unit volume of sandstone. The Burro Canyon and related

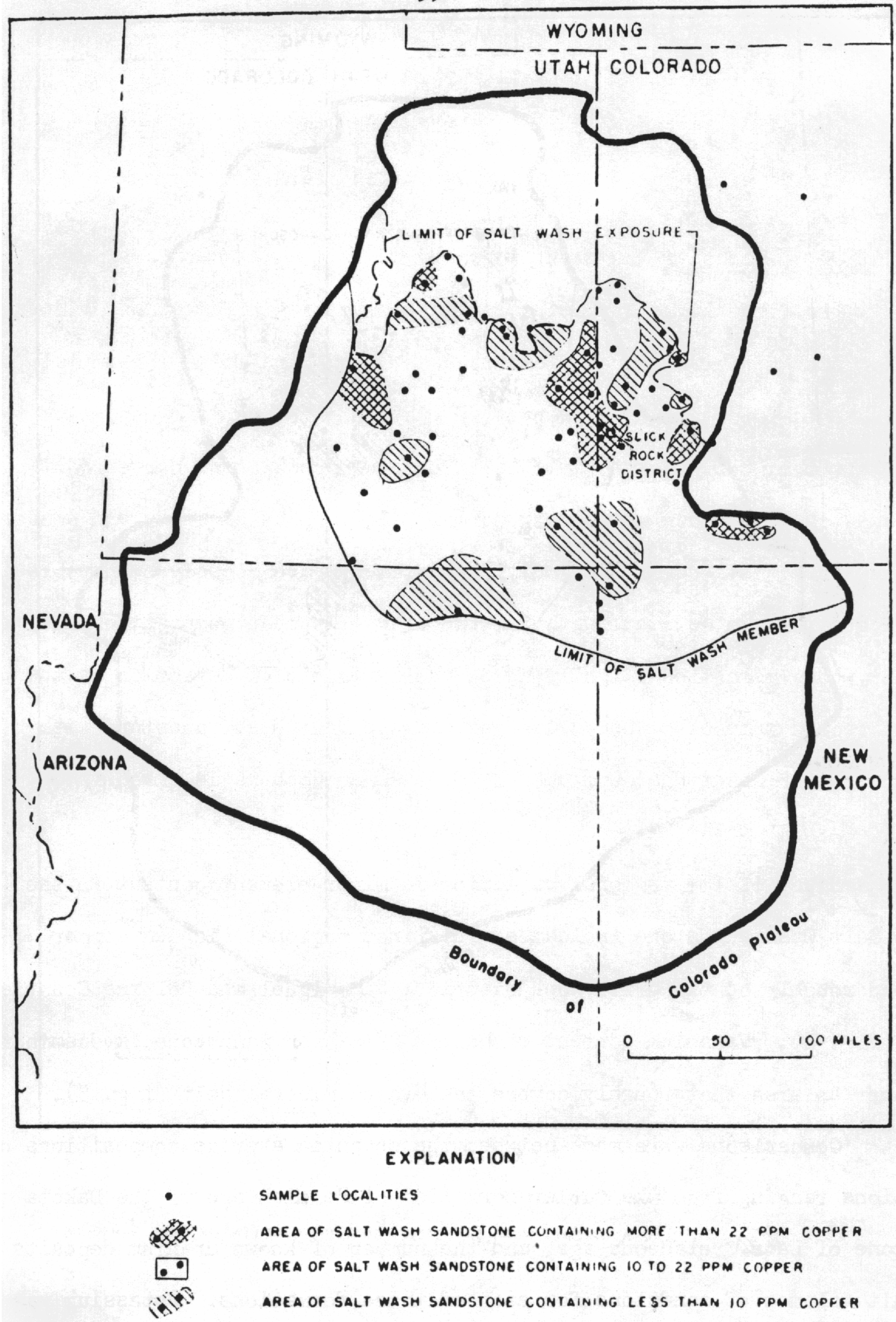


Figure 4. MAP OF THE COLORADO PLATEAU SHOWING SAMPLE LOCALITIES AND THE DISTRIBUTION OF COPPER IN BARREN SALT WASH SANDSTONE

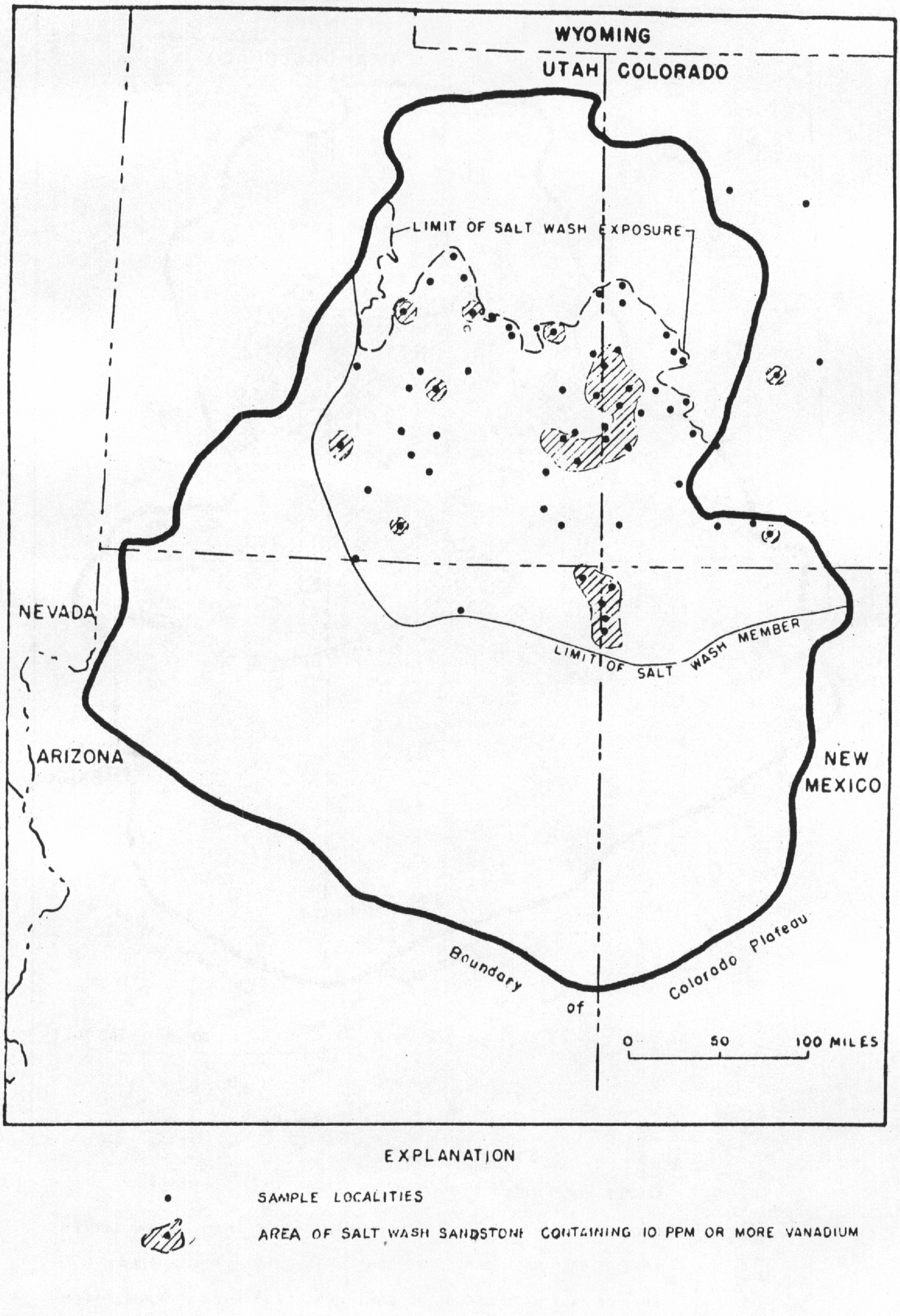


Figure 5. MAP OF THE COLORADO PLATEAU SHOWING SAMPLE LOCALITIES AND AREAS OF BARREN SALT WASH SANDSTONE CONTAINING AT LEAST 10 PPM VANADIUM

Table 1.--Comparison of Salt Wash sandstone with "average" sandstone (composition given in arithmetic mean grams per metric ton)

Element	Salt Wash SS 1/	Average SS 2/
Si	>100,000	367,500
Al	14,600	25,300
Fe	3,000	9,900
Mg	4,000	7,100
Ca	72,000	39,500
Na	2,100	3,300
K	4,430	11,000
Ti	640	960
Zr	150	not given
Mn	380	trace
Ba	630	170
Sr	70	<26
Cu	20	not given
Cr	9	68-200
V	18	20
Co	0.35	0
Ni	0.4	2-8
Ag	0.46	0.44
Y	2.8	1.6
B	13	9-31
Yb	0.4	not given
U	1.3	1.2

1/ Composition calculated from 96 samples.
2/ Rankama, Kalervo, and Sahama, Th. G., Geochemistry: Univ. of Chicago Press, 1950, table 5.52, p. 226.

Early Cretaceous formations and the Dakota sandstone were found to have an average potassium content comparable to that of the Shinarump conglomerate and various members of the Morrison formation. This suggests that the Dakota sandstone may be especially worthy of prospecting in the southern part of the Colorado Plateau, south of the limit of the underlying Brushy Basin member of the Morrison formation.

Compilation of published analyses of igneous rocks of the Colorado Plateau (literature exclusive of 1954) has shown trends in composition. Except for alkaline basaltic rocks and their differentiates, nearly all the igneous rocks are normal calc-alkaline types. The lavas of the strato volcanoes of the southern Colorado Plateau, the lavas of the Marysvale region, the laccolithic rocks of the central Colorado Plateau and San Juan and West Elk Mountains all show essentially the same trend of total alkali-total iron-magnesia ratio, a trend that fits closely the trend of Daly's average basalt, andesite, latite, and rhyolite.

Comparison of the soda-potash-lime proportions and spectrographic analyses reveal that the laccoliths of the Colorado Plateau can be separated into two groups of contrasting composition. Review of previously published work coupled with reconnaissance field studies confirms the belief that the laccoliths of the Colorado Plateau and adjacent San Juan Mountains are of at least two and probably three or more widely separated ages. Laccoliths of the West Elk Mountains and of the eastern part of the Colorado Plateau and adjacent San Juan Mountains are of post-Early Eocene and of Miocene (?) or post-Miocene (?) age. These laccoliths are characterized by moderately high radioactivity, by high lead and rare earths (figs. 6 and 7), and by a ratio of soda to potash of near one.

Laccoliths of the central Colorado Plateau, including the Rico, La Plata, Ute, Carrizo, La Sal, and Henry Mountains, are characterized by low radioactivity, low lead and rare earths (figs. 6 and 7), and by a soda to potash ratio between one and two. Facies changes and types of porphyry in pebbles and cobbles of the McDermott member of the Animas formation, of latest Cretaceous age, suggest that the La Plata Mountains, a member of the central Colorado Plateau group, were a major source of the igneous detritus in the McDermott member. A spectrographic analysis of porphyry from the McDermott member compares closely with the analyses of laccolithic rocks of

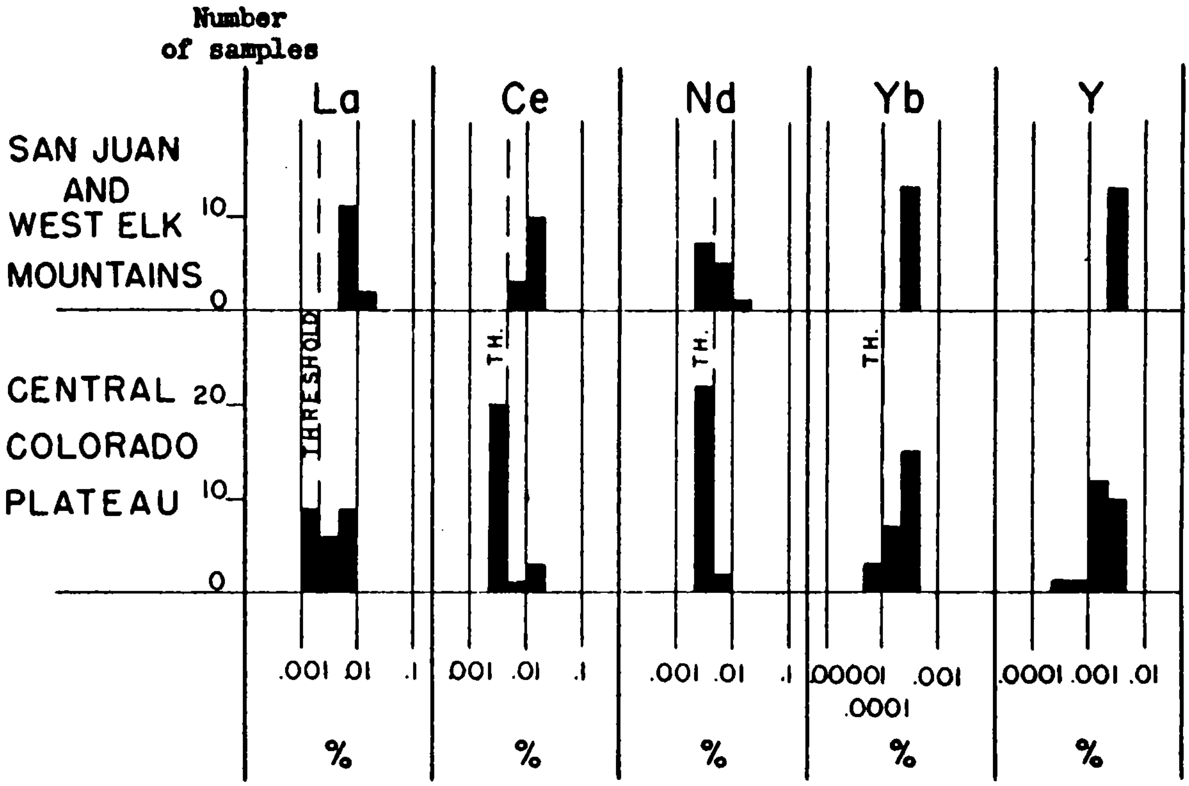


Figure 6. Histograms comparing rare earths in laccolithic rocks from the San Juan and West Elk Mountains with intrusive rocks from the laccolithic mountains of the central Colora‹› Plateau

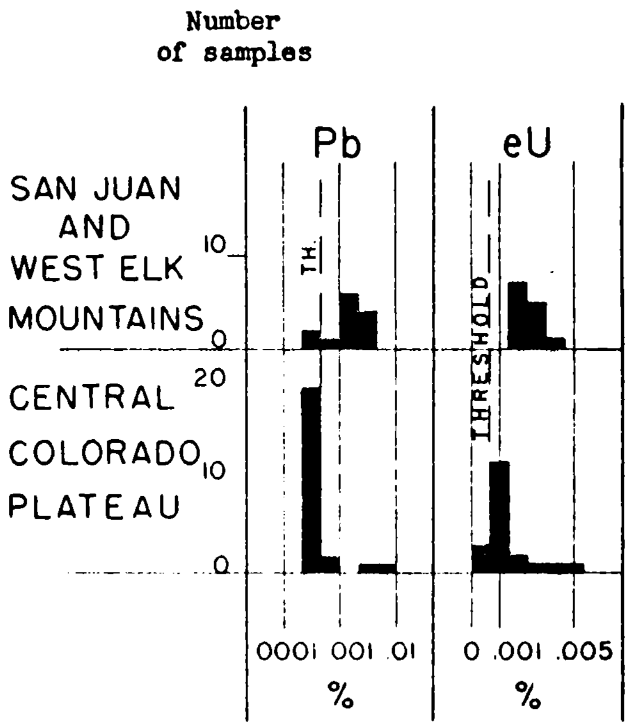


Figure 7. Histograms comparing lead and radioactivity of laccolithic rocks from the San Juan and West Elk Mountains with intrusive rocks from the laccolithic mountains of the central Colorado Plateau

central Colorado Plateau. It is suggested that the central Colorado Plateau laccoliths are of probable latest Cretaceous age, rather than of mid-Tertiary age, as suggested by previous writers.

Petrographic study of the igneous rocks from the Ute Mountains shows that differentiation between phenocryst and groundmass phases in a single sample of diorite porphyry essentially duplicates the chemical and mineralogical differentiation in the Ute Mountains rocks, which range from basic diorite porphyry to quartz monzonite porphyry. Fractional crystallization is therefore indicated as a possible, if not likely major factor, in the origin of this simple differentiation sequence. The data are also compatible with fractional fusion and assimilation of granite as major factors in the differentiation of the Ute Mountains rocks.

The variation of minor elements in the differentiation sequence of the Ute Mountains intrusives mainly follows trends normal for calc-alkaline rocks (fig. 8). Among the elements of interest, the percentages of vanadium, copper and cobalt decrease in the more acid differentiates and the percentage of nickel appears to show an anomalous tendency to increase. In the lavas of the San Francisco Mountains (fig. 9) and Marysvale volcanic fields, percentages of vanadium, copper, nickel, and cobalt decrease sharply whereas the percentage of lead increases toward the rhyolite end of the differentiation sequence, as is the case for normal calc-alkaline rocks. The intrusive rocks of the Henry Mountains laccolithic group appear to exhibit alternative modes of differentiation. One trend is like that of the Ute Mountains whereas in another, shown by monzonite porphyries, vanadium and copper as well as lead and rare earths are enriched in the more acid rocks.

The laccolithic rocks of the central Colorado Plateau, with minor exceptions, are all closely comparable in trace element composition. Among

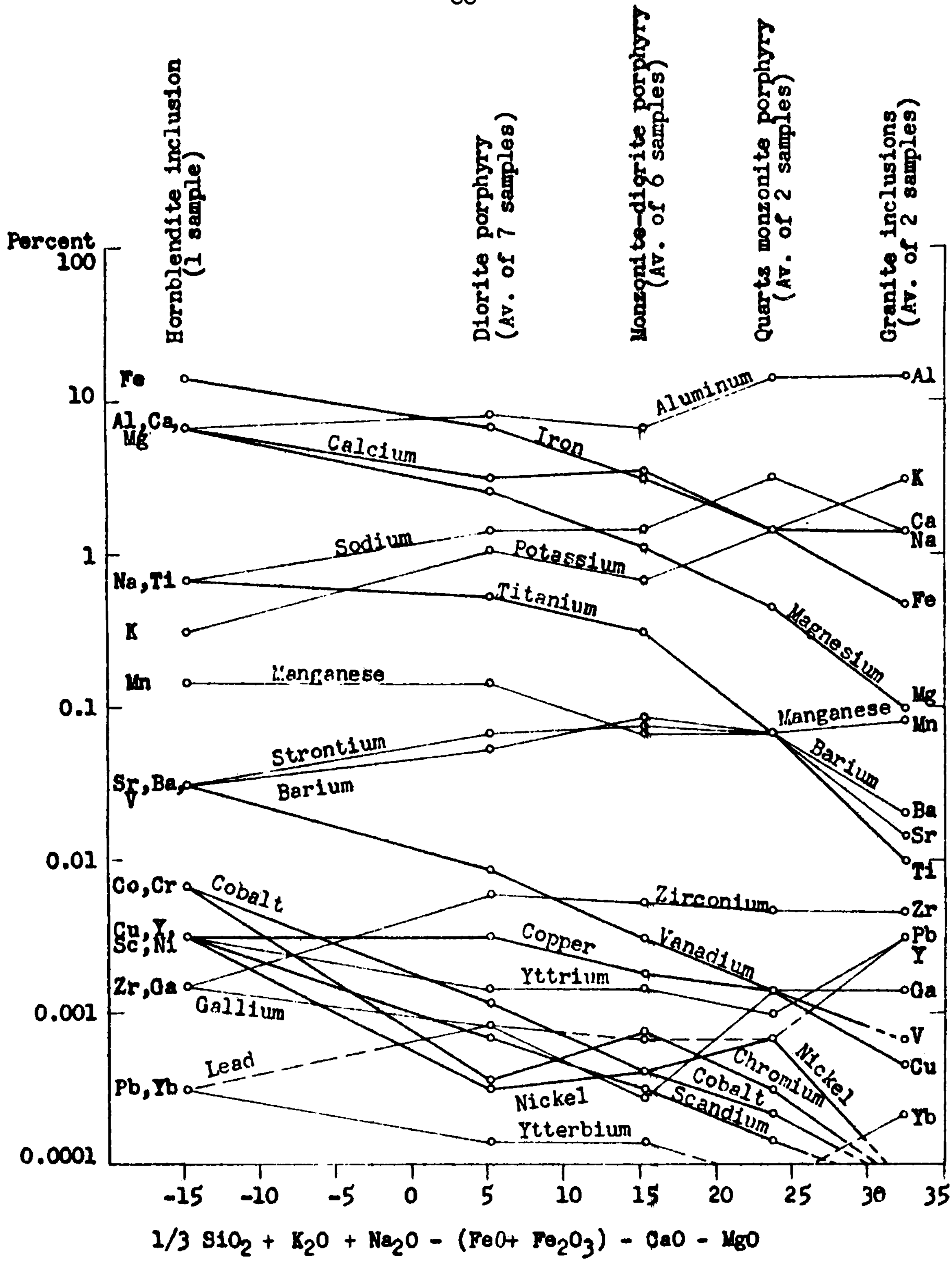


Figure 8. Variation diagram of elements, as determined spectrographically, in the igneous rocks of the Ute Mountains, Colorado

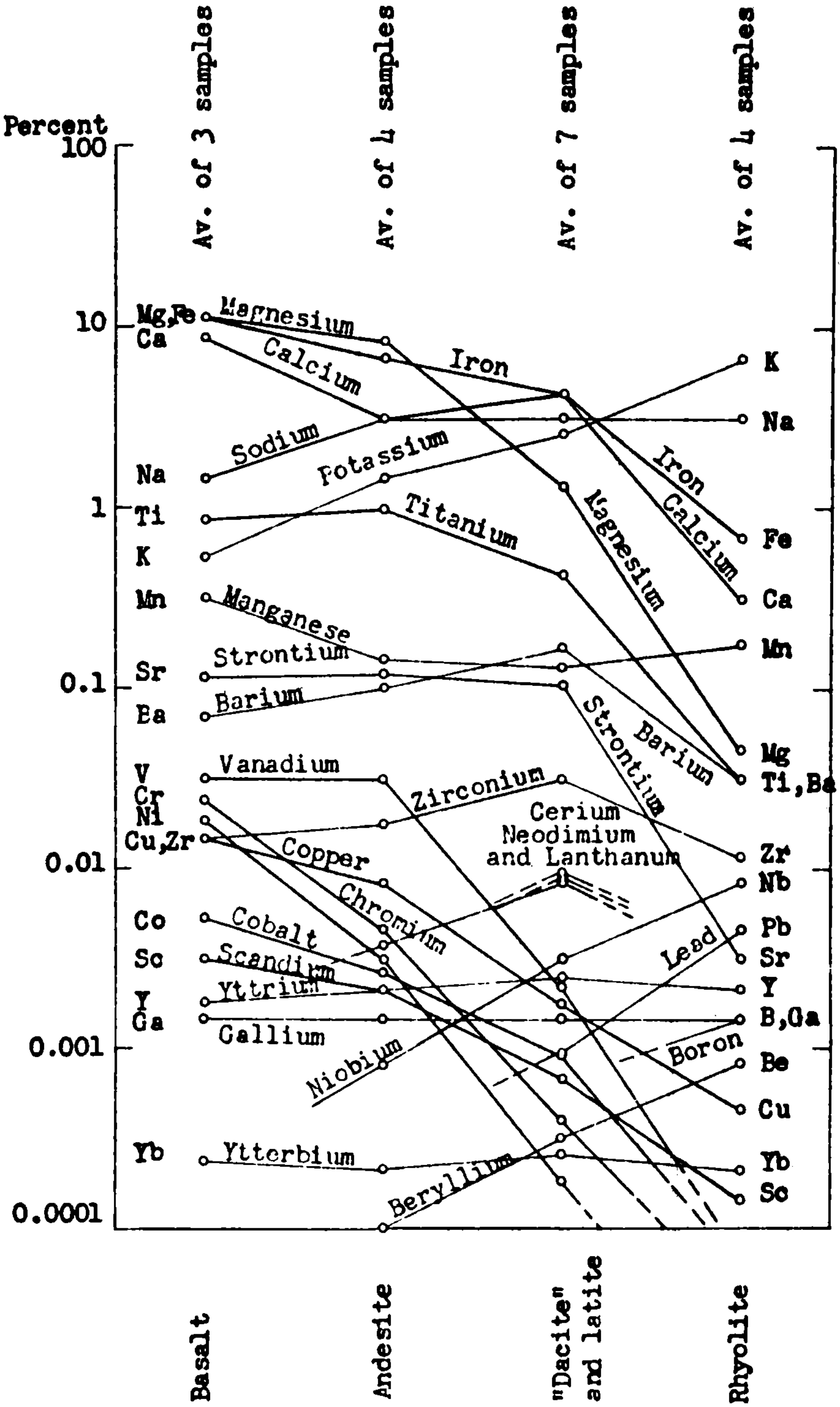
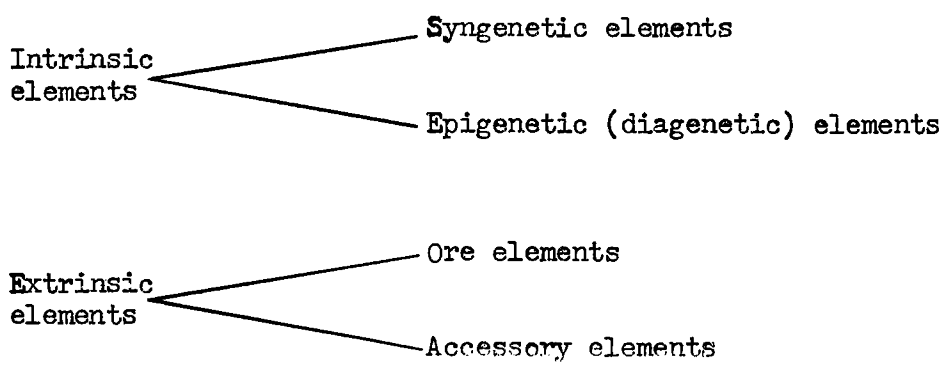


Figure 9. Variation diagram of elements, as determined spectrographically, in the lavas of the San Fransiscan volcanic field, Arizona

the laccolithic groups studied to date, however, the rocks of the Ute Mountains appear to be slightly deficient in the trace element suite that is concentrated in the uranium deposits of the Colorado Plateau. Vanadium shows an anomalous tendency to be enriched in the monzonite of the Henry Mountains and the syenite of the La Plata Mountains, and copper is anomalously enriched in the monzonite of the Henry Mountains and the syenite of the La Sal Mountains.

Study of the altered igneous rocks in the Ute Mountains shows that the suite of metals subject to transportation, both those introduced and those leached, during alteration includes the metals introduced into uranium deposits that are localized along faults thought to be related to intrusion of the Ute Mountains igneous rocks. Solutions related to igneous activity are thus shown to be a potential source of the metals introduced in these uranium deposits.

Study of the composition of 211 uranium deposits from the Jurassic Morrison formation and 38 uranium deposits from the Triassic formations of the Colorado Plateau has led to the following classification of elements in sandstone-type uranium deposits:



Determination of the role played by an element in Colorado Plateau uranium deposits rests upon comparison of the ores with the barren host rocks and upon the statistical dispersion and correlation of the elements in the ores. Classification of the individual elements in average uranium deposits of the Morrison formation is given in table 2. Copper, lead, silver, nickel, cobalt, molybdenum, yttrium, arsenic, and selenium are the principal detectable accessory extrinsic elements.

Table 2.--Classification of elements in Morrison uranium deposits

INTRINSIC	SYNGENETIC	Silicon	Iron	Scandium
		Aluminum	Barium	Lanthanum
		Potassium	Titanium	Gallium
		Strontium	Zirconium	
		(Sodium)*	Chromium	
		(Magnesium)*	Boron	
	EPIGENETIC	Sodium		
		(Potassium)*		
		Calcium		
		Magnesium		
		Manganese		
		(Iron)*		
		(Barium)*		
EXTRINSIC	ORE	Uranium		
		Vanadium		
	ACCESSORY	(Magnesium)*	Copper	Nickel
		(Iron)*	Lead	Cobalt
			Zinc	Molybdenum
			Silver	
		Yttrium	Arsenic	
		Ytterbium	Beryllium	
			Selenium	

* Secondary role played by element.

Statistical analysis of the regional distribution of copper in sandstone uranium deposits shows the distribution is nonrandom. The regional distribution of extrinsic accessory elements in the sandstone type uranium deposits studied is shown in figures 10 through 16. Two major types of regional patterns are exhibited by the elements studied. One type includes an area in which there is a preponderance of high values partially coincident with the region of salt structures. The other type includes an area characterized by a predominance of high values northwest of the Colorado River. The continuity of patterns for all of the metals in general appears to be independent of the stratigraphic positions of the uranium deposits studied.

Copper, silver, and lead belong to the first type of pattern. The prominent "high" that is roughly coincident with the salt structures is also roughly centered on the La Sal Mountains. Essentially nonuraniferous copper deposits within this "high" area lie closer to the La Sal Mountains than do the bulk of the uranium deposits. A rough zonal relation between copper deposits and uranium deposits around the La Sal Mountains may be indicated. Whether this distribution of copper is related in any way to the anomalous rise of copper in the syenitic differentiates of the La Sal Mountains cannot at present be determined. It should also be noted that the copper "high" is partially coincident with the area of high copper in the barren sandstones of the Salt Wash member of the Morrison formation (fig. 10).

Nickel, molybdenum, and selenium belong to the second type of pattern. No geological features are known at present which coincide with this pattern. Yttrium may also follow this pattern partially, but its distribution appears to be more nearly random, possibly because an appreciable proportion of the yttrium in the uranium ores is probably intrinsic.

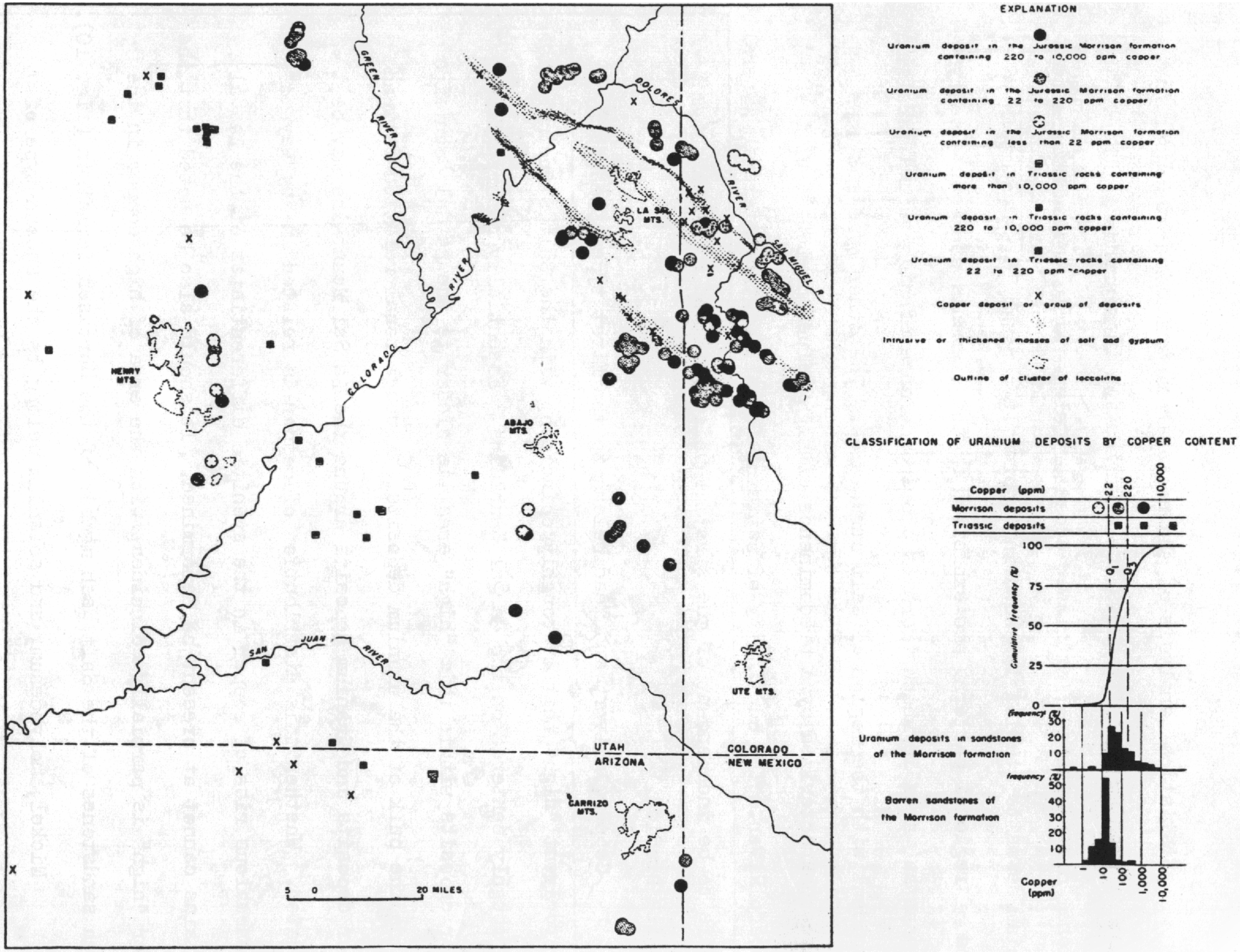


Figure 10. MAP OF PART OF THE COLORADO PLATEAU SHOWING THE DISTRIBUTION OF COPPER IN URANIUM DEPOSITS AND LOCATION OF COPPER DEPOSITS

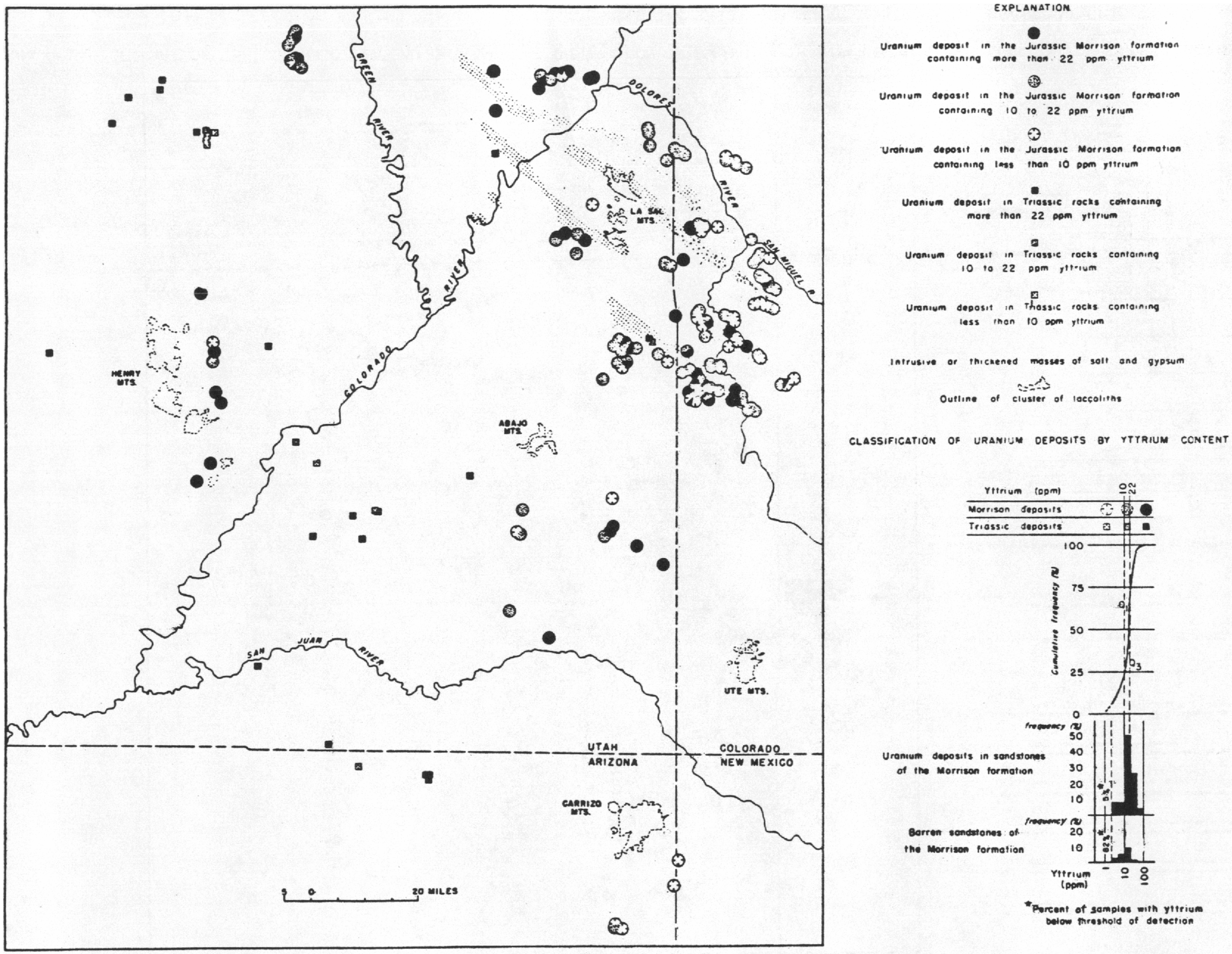


Figure 11. MAP OF PART OF THE COLORADO PLATEAU SHOWING THE DISTRIBUTION OF YTTRIUM IN URANIUM DEPOSITS

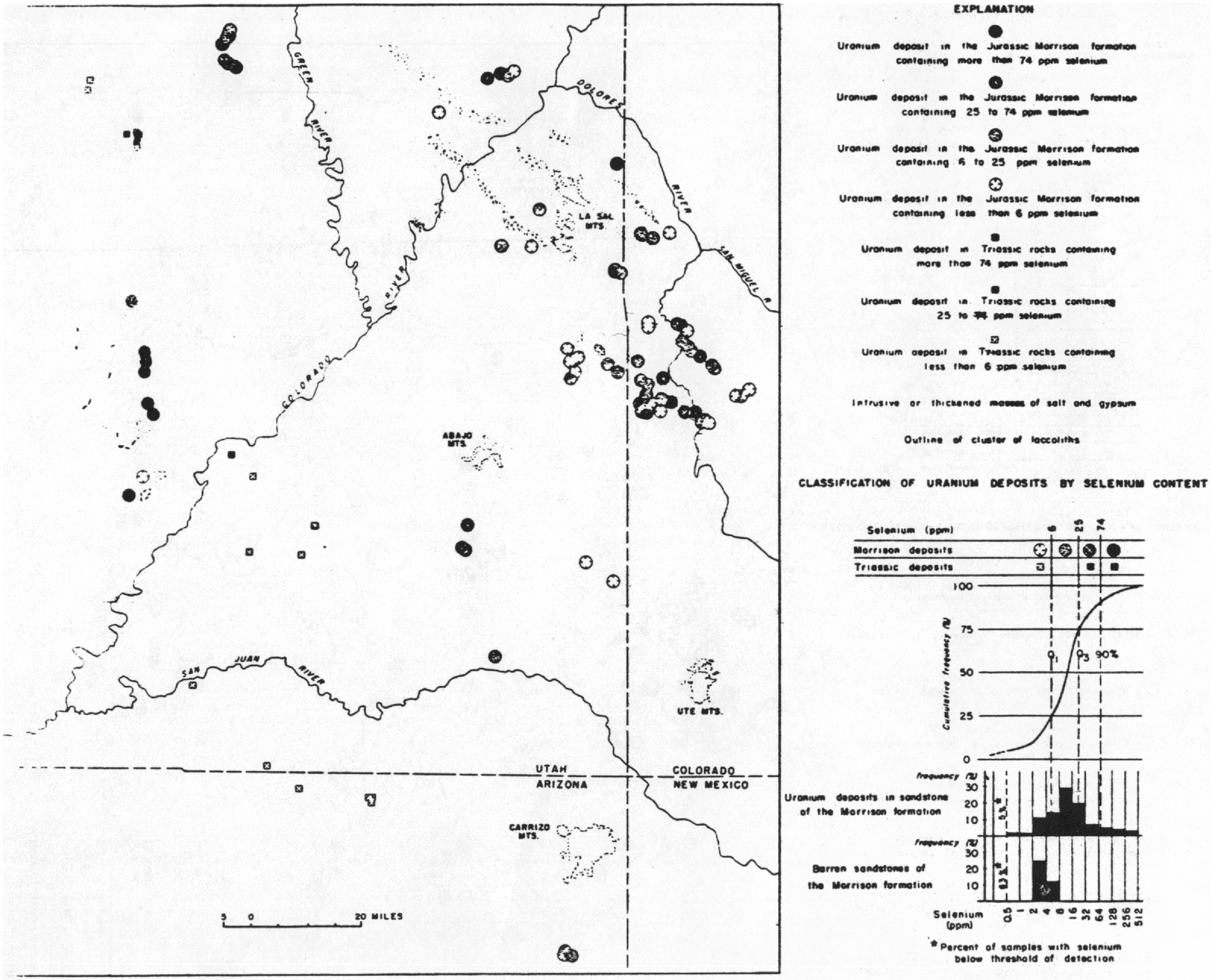


Figure 12. MAP OF PART OF THE COLORADO PLATEAU SHOWING THE DISTRIBUTION OF SELENIUM IN URANIUM DEPOSITS

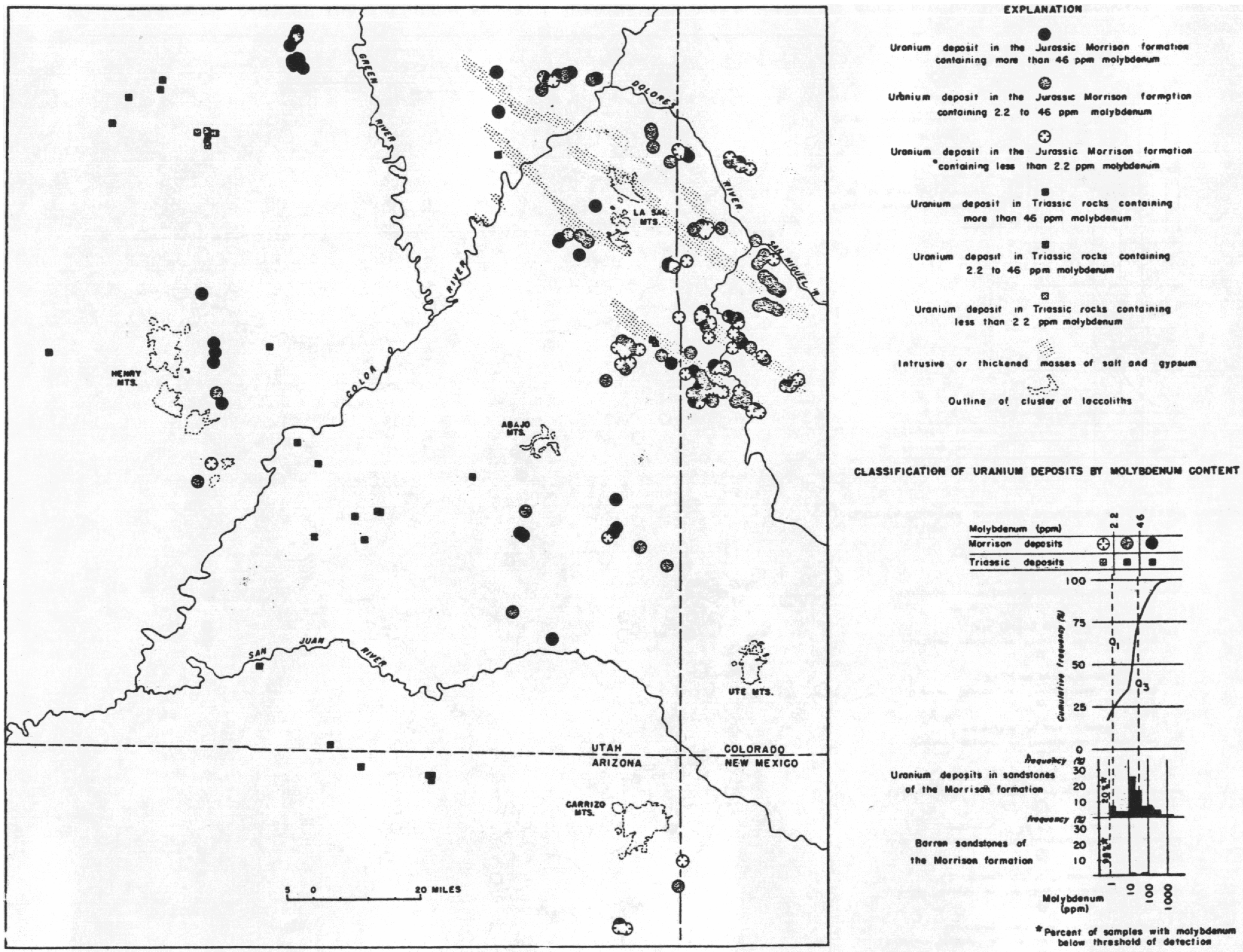


Figure 13 MAP OF PART OF THE COLORADO PLATEAU SHOWING THE DISTRIBUTION OF MOLYBDENUM IN URANIUM DEPOSITS

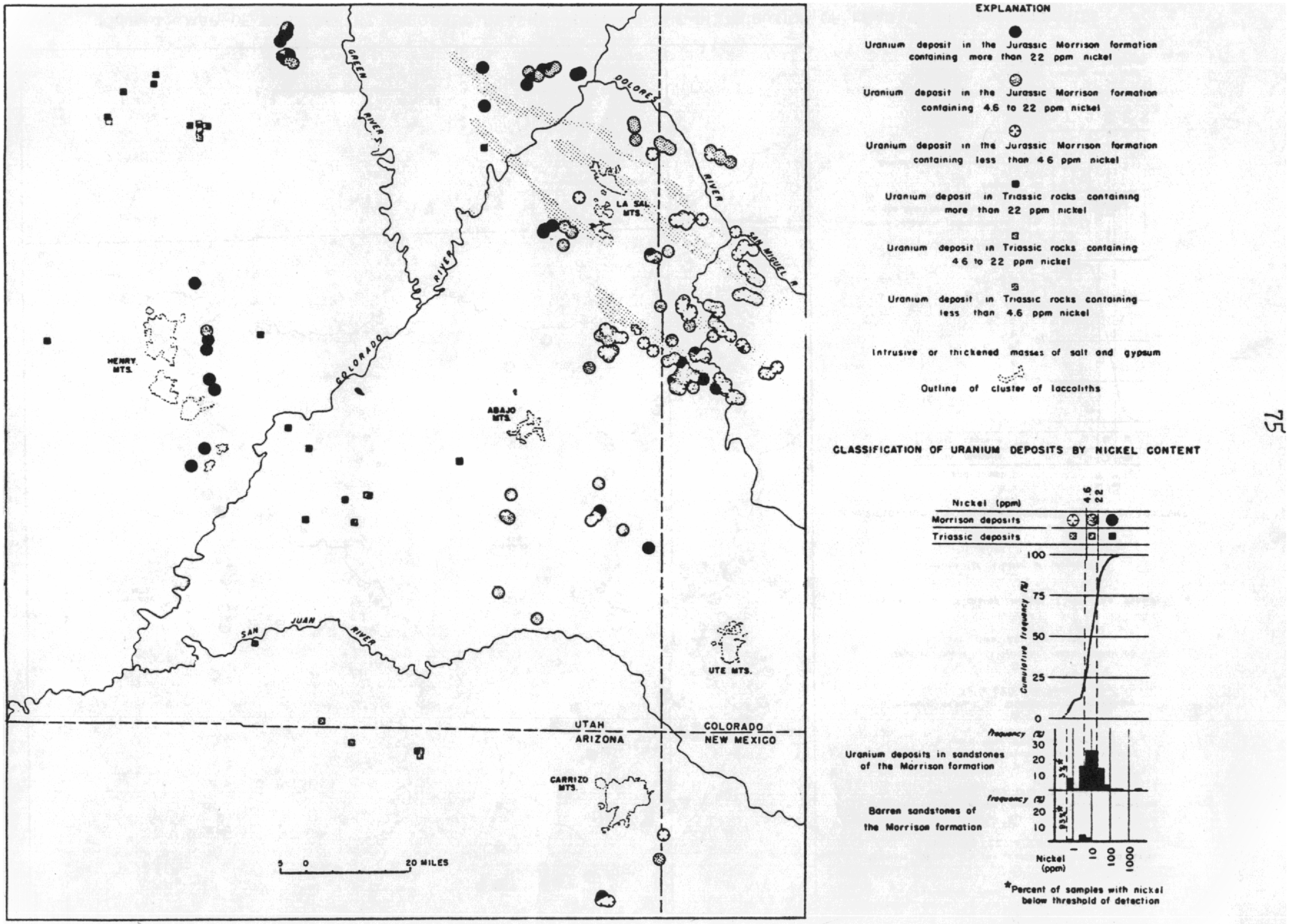


Figure 14. MAP OF PART OF THE COLORADO PLATEAU SHOWING THE DISTRIBUTION OF NICKEL IN URANIUM DEPOSITS

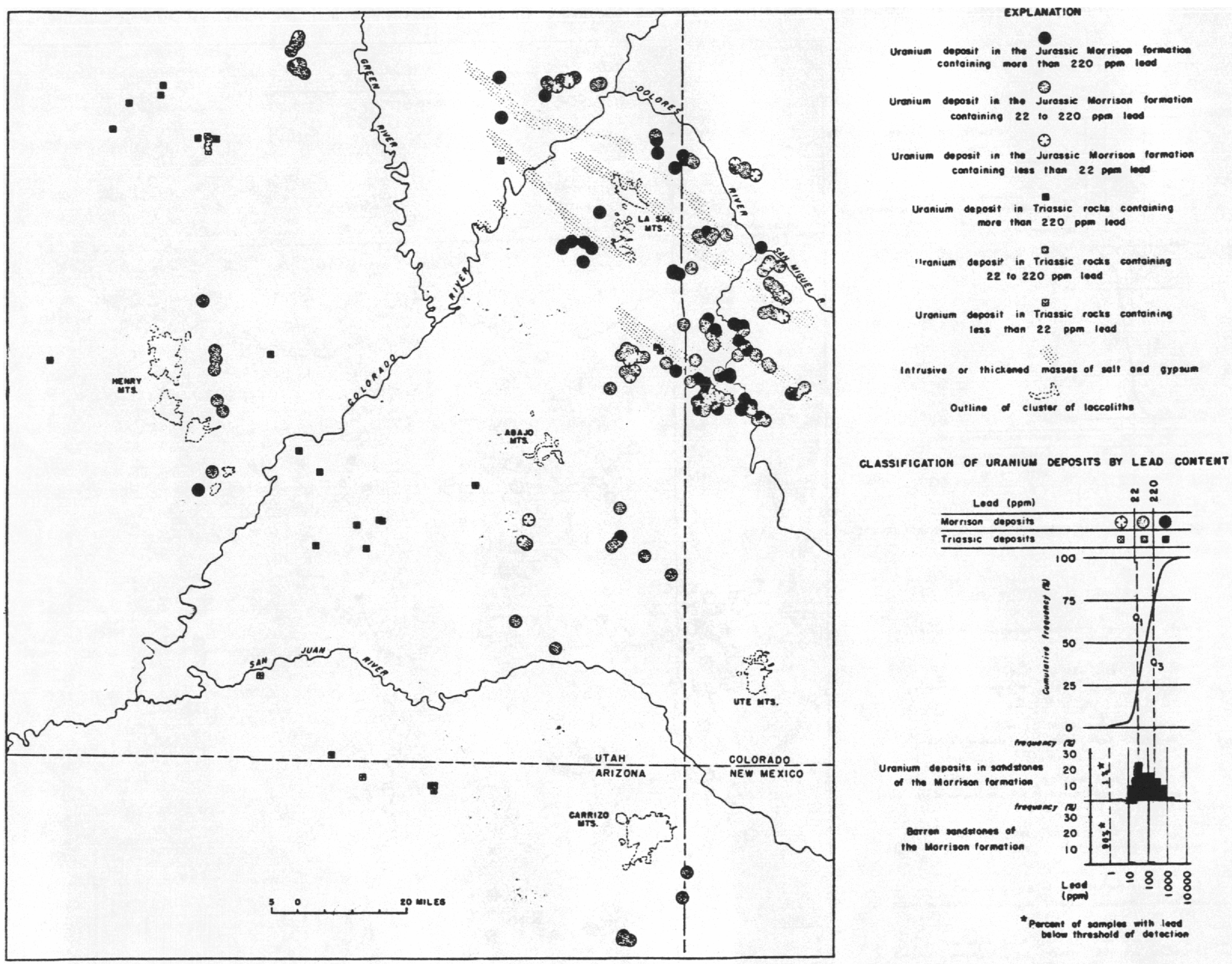


Figure 15. MAP OF PART OF THE COLORADO PLATEAU SHOWING THE DISTRIBUTION OF LEAD IN URANIUM DEPOSITS

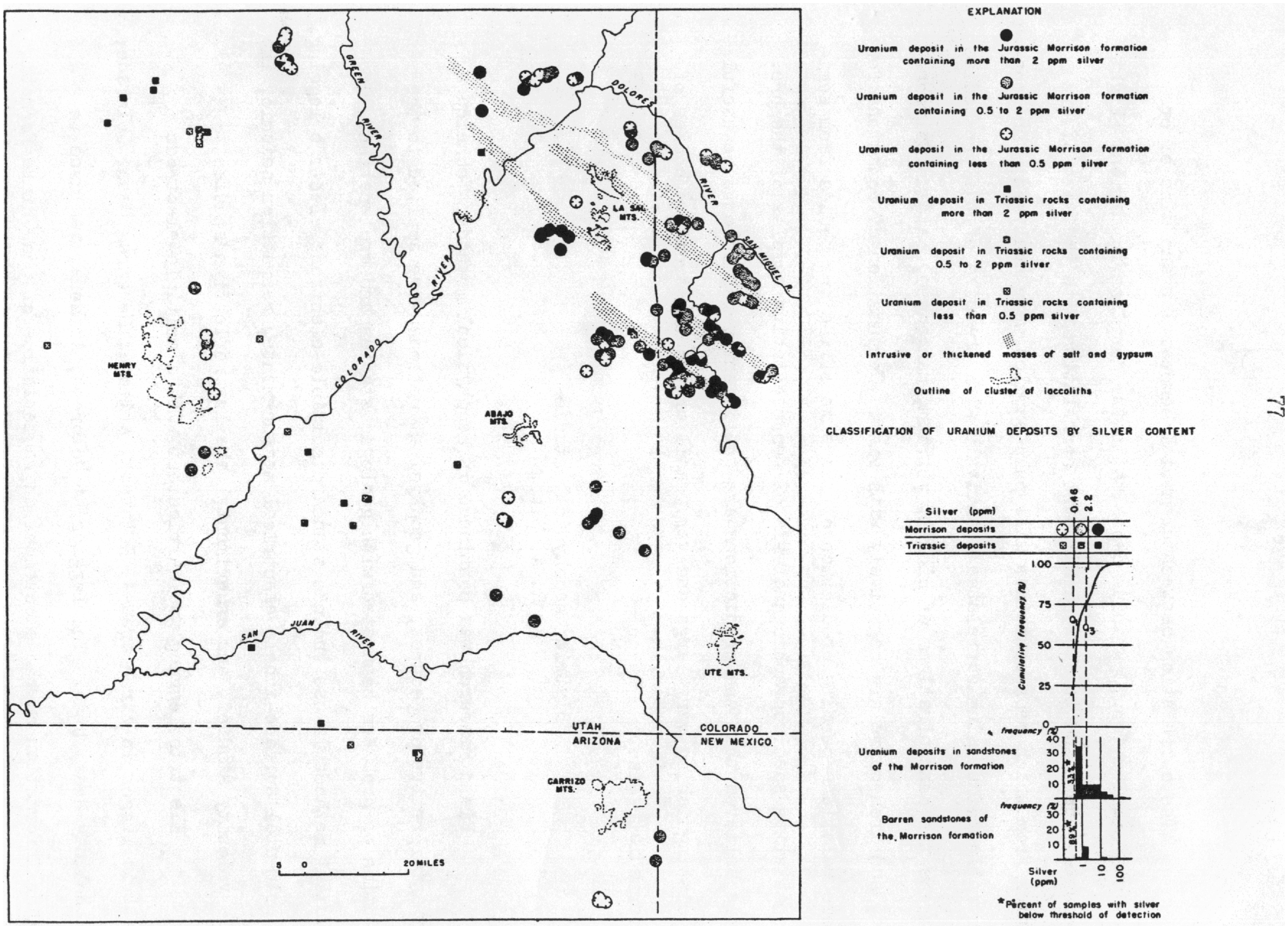


Figure 16. MAP OF PART OF THE COLORADO PLATEAU SHOWING THE DISTRIBUTION OF SILVER IN URANIUM DEPOSITS

The correlation between elemental composition and size of ore body was studied for 70 uranium deposits in the Morrison formation. Eight elements were found to show significant correlation with the size of ore bodies from which representative mill pulp samples were analyzed. The concentration of uranium correlates positively with the size of the ore bodies whereas the concentrations of nickel, yttrium, manganese, calcium, zirconium, and iron correlate negatively with size. Computation of equations for these relations permits prediction of the size of the ore bodies from semi-quantitative spectrographic analysis of representative samples of the ore. It is believed that the predictions are sufficiently reliable to be useful in distinguishing very large and very small ore bodies from ore bodies of intermediate size.

District geophysical studies
By R. A. Black

Field research was continued in geophysical methods, techniques, and interpretive procedures, and geophysical methods were applied to the solution of problems connected with geologic studies and exploration. Geophysical methods in use include standard multiple-electrode electric logging, experimental surface-inhole electrical measurements, refraction seismic, inhole velocity studies, and experimental shallow reflection studies.

Electric logging was carried out with a multiple-electrode electric logger in three areas: Holbrook, Arizona; Monogram Mesa, Colorado; and Holiday Mesa, Utah. The logging at Holbrook, Arizona, was done to gather information on the electrical characteristics of the Chinle formation, to complement surface-inhole electrical work in this area, and to correlate the electric-log data with radiometric data obtained in this area by the AEC.

A total of 95 holes were logged in the Holbrook area. The information obtained is being tabulated and work is in progress on correlation of electric-log data with gamma-ray data. The differences in resistivities between the sandstone, mudstone, and siltstone of the Petrified Forest member of the Chinle formation ("C" division of Gregory) are quite small. The mudstone resistivity is about 10 ohm-meters, the siltstone slightly higher, and the sandstone about 60 ohm-meters.

On completion of electric logging in the Holbrook area drill holes were logged on the Peanut Group of claims in Bull Canyon and on Holiday Mesa, Utah. The Holiday Mesa measurements were made for comparison with the results of the present AEC drilling program in this area, and the Peanut Group measurements are being made to establish drilling guides from a combination of gamma-ray and electric log data.

As considerable instrumental difficulty was experienced with the standard logging equipment, a number of improvements were made to adapt the instrument to Colorado Plateau logging conditions. The oscillator has been replaced with a later type which synchronizes itself with the 60-cycle current supplied to the unit, thus eliminating two tubes and all beat problems. The unit is now working at 30 cycles or one-half the supply frequency. The zero controls have been improved and the RC filter was removed from the input to the current regulator amplifier. Because the neoprene logging cable now used is responsible for much of the leakage that has been causing trouble, an armored cable will be substituted to reduce leakage and improve ground contact by eliminating the surface electrode.

Experimental surface-inhole electrical measurements were made at Holbrook, Arizona and at Deer Flat, Utah. The Holbrook measurements were made to test the equipment and to experiment with various electrode configurations. Previous drilling and electric logging in this area afforded control. The electrode configuration experiments were conducted in an area where the electric logs showed apparent resistivity variations which seemed to be due to changes in thickness of a sandstone layer in the Chinle formation. The basic electrode configurations tested are shown in figures 17 and 18. It was found that the current circle (VI) gives the most satisfactory results, and configurations I, II, and III were the least satisfactory. This initial testing of the equipment resulted in instrumental changes such as the installation of additional basing controls and a variable control on the voltage output.

In the Deer Flat area experimental surface-inhole electrical measurements were made in an attempt to outline a channel in the Shinarump formation that was covered by 200-250 feet of overburden. The drilling on Deer Flat was concentrated near the canyon rims and the most of the surface consists of exposed bedrock with only occasional patches of thin sandy soil. Experiments were made with various types of electrodes in an attempt to improve surface contact. The best results were obtained with one-foot-square pieces of copper screen covered with mud saturated with salt water, but even so the results were not consistent enough to make surface-inhole electrical measurements practical in this area. Topographic differences influence the measurements and cannot be safely ignored. Much of the Colorado Plateau is unsuitable for application of surface-inhole electrical surveys because of the necessity for good ground contact conditions, relatively flat topography, and a suitable electrical contrast between the target and the surrounding material.

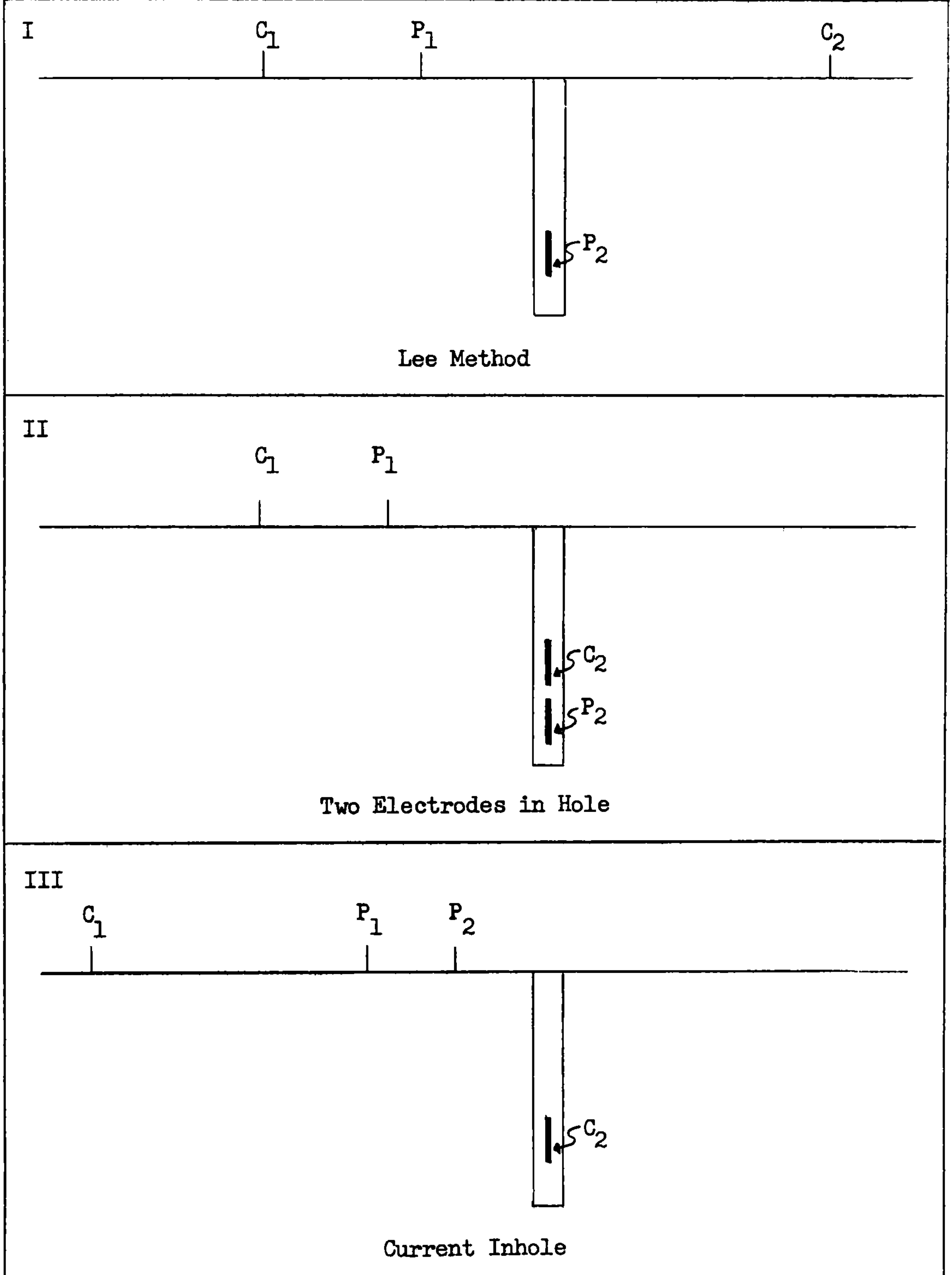


FIGURE 17. EXPERIMENTAL ELECTRODE CONFIGURATIONS TESTED IN HOLBROOK, ARIZONA

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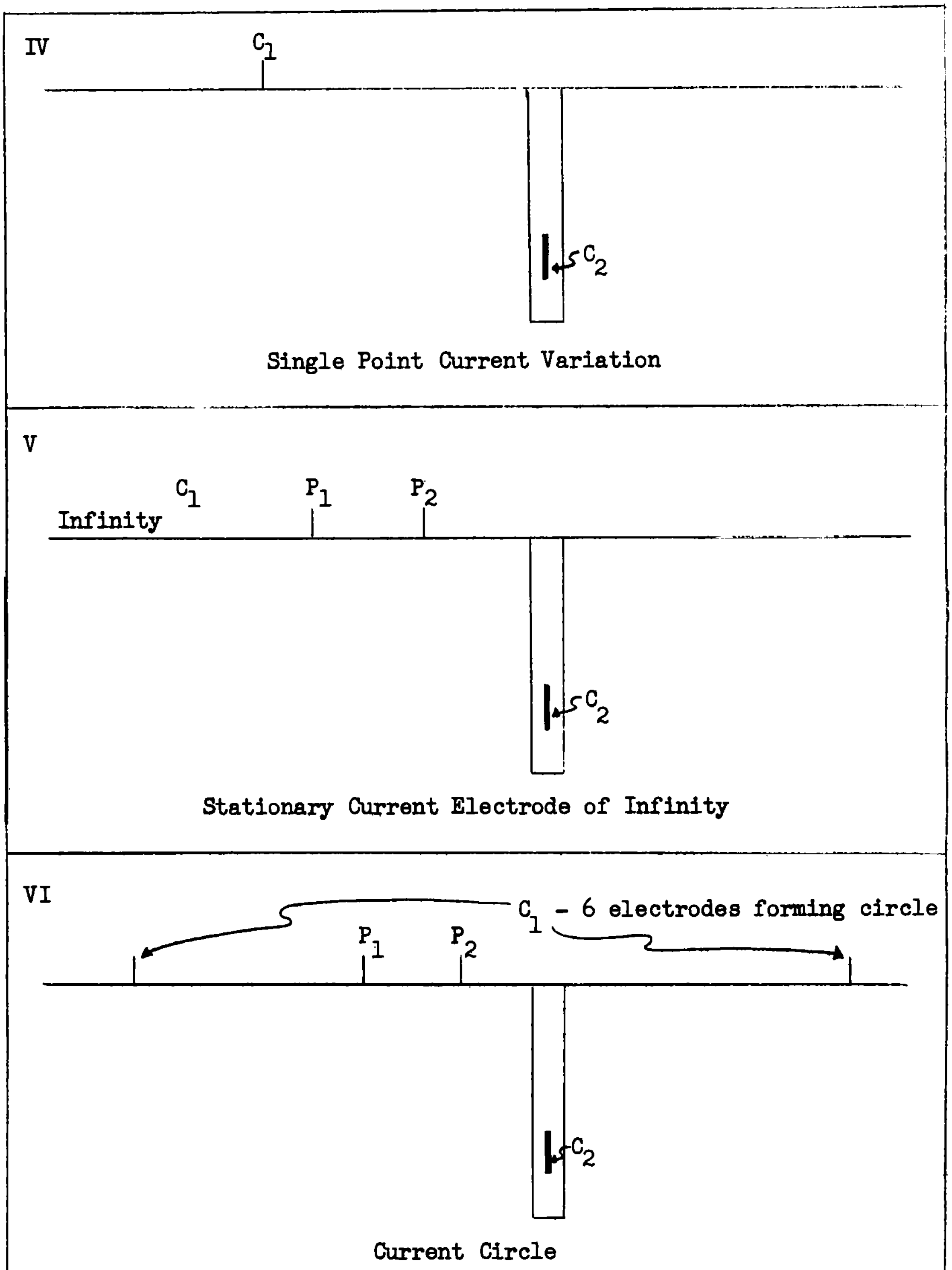


FIGURE 18. EXPERIMENTAL ELECTRODE CONFIGURATIONS
TESTED IN HOLBROOK, ARIZONA

Seismic refraction field work was carried out on Holiday Mesa, Utah; Mitchell Mesa, Arizona; Deer Flat, Utah; and in Oljeto Wash, Arizona. Some of this work was concerned with the application of techniques developed by previous work in Monument Valley, and part with refinement of existing techniques and experimental surveys to test new applications of the seismic refraction method.

A seismic refraction survey was made on Holiday Mesa prior to exploration drilling by the AEC to determine the trend and depth of a channel on this mesa. Excellent results were obtained.

A seismic refraction survey was also made on Mitchell Mesa, Arizona to detail the Mitchell Mesa channel to aid in planning a drilling program. The trend, width and depth of the channel were determined. Wide-spaced reconnaissance lines were also shot over the mesa top but no other channels were discovered.

Experimental seismic refraction tests were made in Deer Flat, Utah, in an attempt to map the Shinarump-Moenkopi contact through approximately 250 feet of overburden including alluvium and the Mossback sandstone and Monitor Butte members of the Chinle formation ("D" division of Gregory). The Monitor Butte member seems to have a higher velocity than the Shinarump, which tends to mask the Shinarump, and thus makes it difficult to determine the Shinarump-Moenkopi contact with accuracy. The experimental work in Deer Flat was shot with various charges and spread lengths on a grid laid out by the geologist. Preliminary examination of the data indicates that it may be possible to map the top of the Moenkopi in this area.

A large scale seismic refraction program was initiated in the Oljeto Wash area of Arizona, which consists of a broad sand-covered valley with few outcrops. This program is the culmination of several years of geologic and seismic studies in the Monument Valley area, and it is hoped that channels will be discovered that do not crop out. The results should also serve as a demonstration of the use of the seismic refraction method for uranium exploration.

A permanent camp has been set up for the seismic crew, and surveying of the approximately 30 square miles has been completed. Reconnaissance lines are being shot along section lines to locate the most suitable areas for more detailed surveys.

In-hole seismic velocity studies were carried out in a number of areas this summer with the in-hole velocity cable using crystal detectors. The results will be used as part of a tabulation of physical properties of the various Colorado Plateau formations.

Experimental shallow reflection measurements were carried out to determine if usable shallow reflections could be obtained under the stratigraphic conditions present on the Colorado Plateau. This preliminary work was chiefly concerned with the development of shallow reflection techniques, and with refinement of operating techniques. Field tests were made in the following areas: (1) Nokai Mesa, Arizona, where measurements were made directly on top of the Shinarump conglomerate over known channels; (2) Deer Flat, Utah, where the Shinarump conglomerate is overlain by approximately 200 feet of overburden including alluvium, Mossback sandstone, and mudstones and sandstones of the Chinle formation; and (3) Monogram Mesa, Colorado, where the Salt Wash is covered by 200-900 feet of overburden including the Brushy Basin member of the Morrison formation and the Burro Canyon formation.

Field work on the shallow reflection program has been recessed until spring. Preliminary examination indicates that shallow reflections were obtained in all three of the test areas, although they were often discontinuous and showed erratic step-outs which make interpretation difficult. More work is planned for the spring, in particular using pattern charges and multiple geophones, to improve the character of the records. If the record character can be improved, it is possible that this technique may have a considerable application in problems of uranium exploration.

Regional geophysical studies
by H. R. Joesting

Aeromagnetic surveys

Aeromagnetic surveys covering about 16,000 square miles have now been flown in connection with the Plateau Regional Studies (fig. 19). This includes about 3,900 square miles in the Green River Desert--Henry Mountains region of Utah, flown in October 1954. In addition, some 4,000 square miles in the Uravan--Moab and the Lukachukai areas were flown prior to fiscal year 1954 and are available for the Regional Studies. No additional aeromagnetic surveys are contemplated at this time except of a few small areas where additional data are required.

Gravity surveys

Regional gravity surveys made to date are shown in figure 20. During the past six months fill-in gravity surveys were completed in the Inter-River area, Utah, and the Gateway--Egnar area, Colorado. Details of the additional coverage in the Gateway--Egnar area are shown in figure 21.

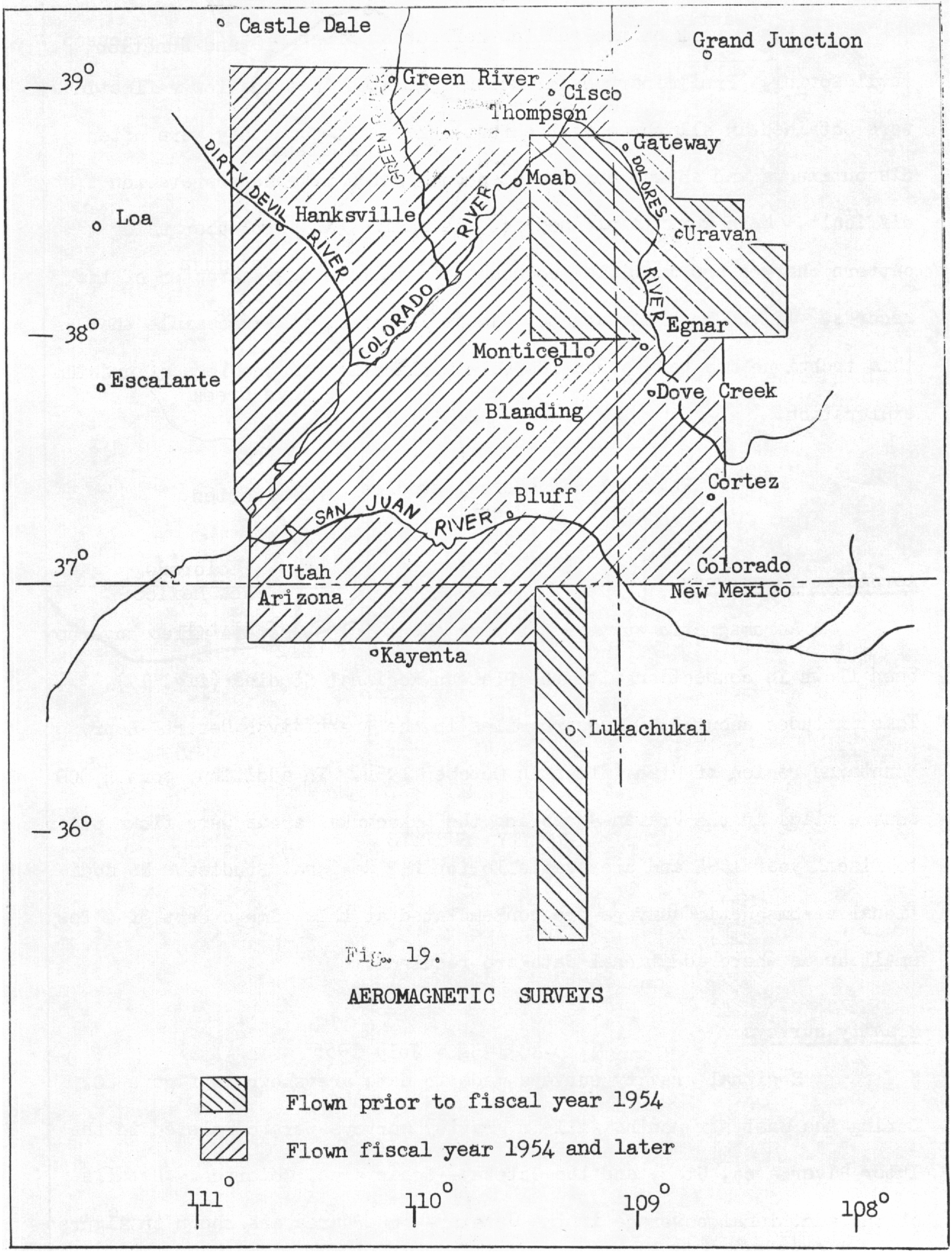


Fig. 19.

AEROMAGNETIC SURVEYS

Flown prior to fiscal year 1954

Flown fiscal year 1954 and later

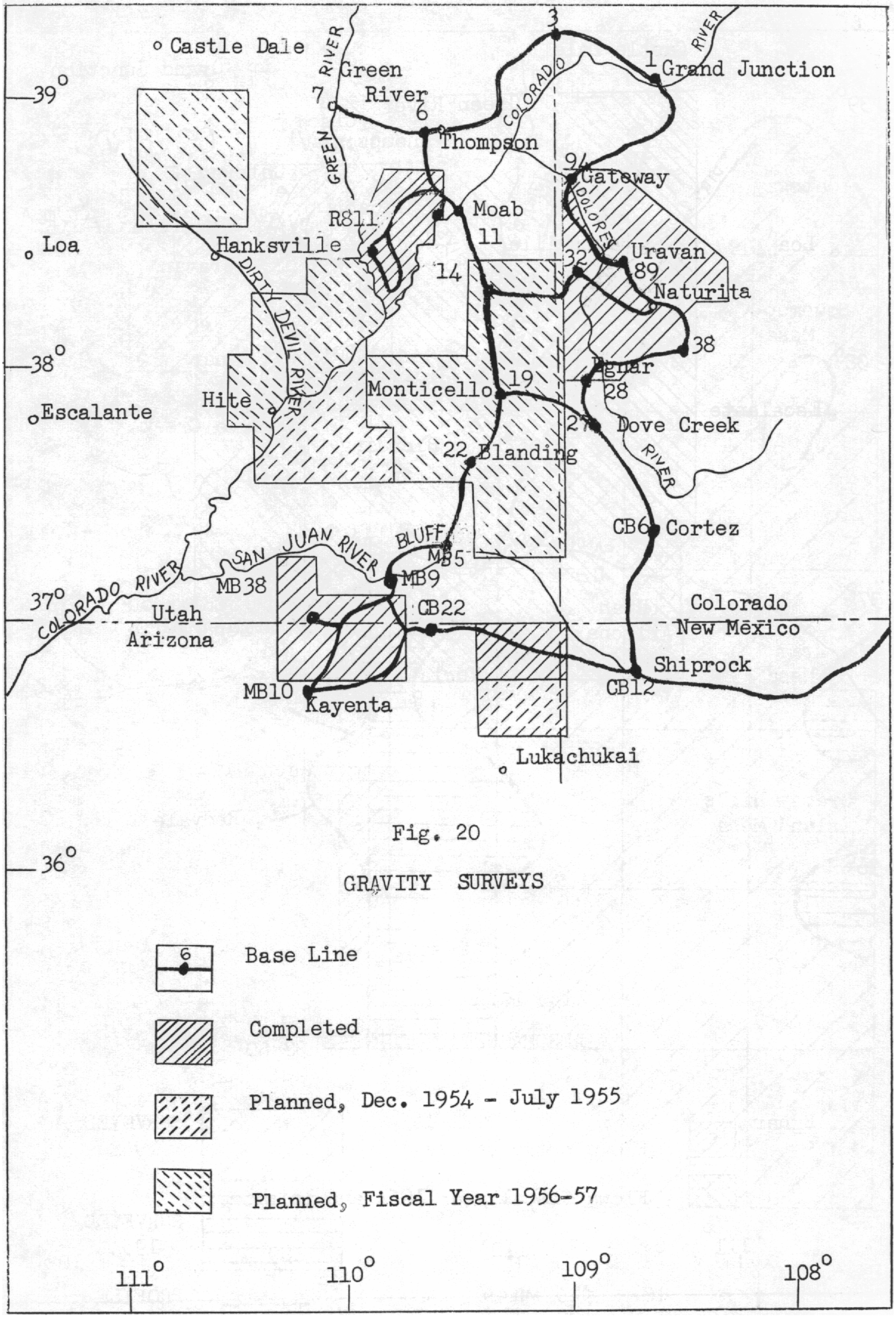
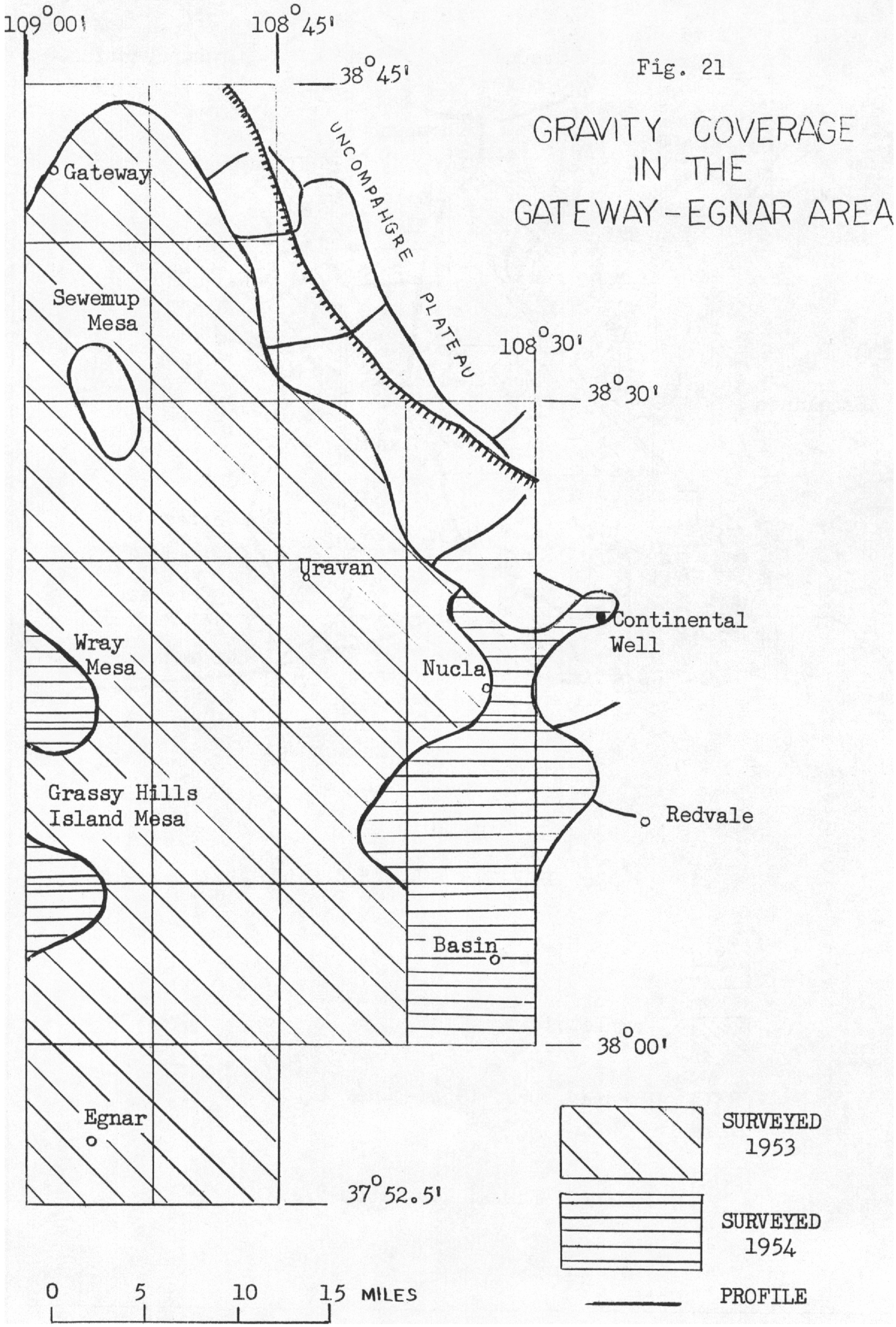


Fig. 20

GRAVITY SURVEYS

Fig. 21

GRAVITY COVERAGE IN THE GATEWAY-EGNAR AREA



A preliminary gravity survey was made of eight $7\frac{1}{2}$-minute quadrangles in the Carrizo Mountains area in northeast Arizona (figure 20). This survey will be extended to cover an additional eight quadrangles if weather conditions permit.

A total of about 200 miles of base lines have been added to existing lines during the past six months to permit reducing all gravity values to a common datum. Base lines completed to date are shown in figure 20. Closing errors were small; for a 370-mile line from Grand Junction to Uravan, Egnar, Dove Creek, Monticello, Moab, Thompson and back to Grand Junction, the closing error was only 0.35 mgal. Other base lines have proportionately small closures.

A total of about 1,800 gravity stations have been established, of which about 500 were established during the summer of 1954. All are tied to the Coast and Geodetic Survey pendulum station at Egnar, Colorado, through base stations.

Altimetry has been used extensively to establish elevations of gravity stations in the quadrangles covered by multiplex maps with a 40-foot contour interval, and on traverses across the front of the Uncompahgre Uplift where no topographic maps are available. Double-base, single-base and no-base altimetric methods were used, depending on the availability of bench marks, the length of traverse, and on topography and atmospheric factors related to topography.

The average error in altimetric elevation is somewhat less than five feet, though errors at a few stations approach 10 feet. This corresponds to gravitational errors of 0.3 and 0.6 mgal respectively. Maximum elevation errors in the two reconnaissance lines across the Uncompahgre front are about 20 feet.

Related investigations

About 50 oriented specimens were taken from diorite laccoliths and sills in the Carrizo and La Sal Mountains, and from minette-type sills near Shiprock. In addition, about 300 randomly-oriented specimens of intrusive and extrusive igneous rocks and of pre-Cambrian crystalline rocks from various localities were furnished by Survey geologists or were collected during the summer. Determinations of magnetic susceptibility and density, and where possible of remanent magnetization, will be made on these specimens to aid in the interpretation of magnetic and gravity data.

Subsurface information on Paleozoic stratigraphy and on the pre-Cambrian basement was obtained from oil companies and other sources. This information, while somewhat scant, will be invaluable in relating geophysical data to geology.

Ground magnetometer surveys of small areas were made at Upheaval Dome in the Inter-River area, on La Sal Mountains and on the San Rafael Swell.

Analysis of results

A ground magnetometer survey in the Upheaval Dome area, Utah, showed that the previously reported magnetic high centers over the west edge of the crater, rather than over its center. Preliminary results of a gravity survey indicate a gravity high coinciding approximately with the magnetic high, but with a small gravity low near its crest. It thus appears likely that Upheaval Dome is underlain by comparatively shallow basement or other basic rock, and that the sharp domal structure is caused by a salt intrusion. Additional gravity stations are required to check the validity of this interpretation.

Reconnaissance ground magnetometer surveys over several areas of altered rock in the San Rafael Swell, Utah, show essentially no anomalies. It thus appears unlikely that igneous rocks are associated either with the rock alteration or with the altered areas, at least not at shallow depths.

Reconnaissance ground magnetometer surveys were made over parts of La Sal Mountains, Utah, to determine the cause of two negative magnetic anomalies. Results showed that they were related to topography rather than to inverse magnetization of the diorite.

Plans

Preliminary regional gravity surveys will be made in the Carrizo Mountains and the White Canyon--Elk Ridge area as shown in figure 20. Fill-in surveys will be made in the Monument Valley area to permit preparation of a final regional gravity map. Field work will be recessed during December and January, and gravity data will be reduced at an increased rate during the winter.

As modern topographic maps become available, gravity surveys will be made to join the areas already covered.

Geothermal measurements will be made in deep diamond-drill holes in the Temple Mountain area, San Rafael Swell, through the cooperation of the Exploration Division, Grand Junction Operations Office, AEC. Cores will also be made available by the AEC for thermal conductivity measurements. For deeper measurements, to 4,000 feet, power driven equipment is under construction in the instrument shops of the Geological Survey.

It is hoped that sufficient geothermal information will eventually become available to permit computing temperature gradients and heat flow from the earth's crust in various parts of the Colorado Plateau. If, as appears possible, the ultimate source of the uranium is in the underlying crustal rocks, then the heat flow from these rocks may be anomalously high.

Original-state core studies
by G. E. Manager

The San Francisco office of the U. S. Bureau of Mines has made an extensive series of analyses of cores from the "blue-black" ore and country rock in the Bitter Creek area. The most notable result is that, as in the carnotite ore section of the Long Park drill hole (LP-530), a definite increase in the water content of the ore-bearing sandstone was found in and below the blue-black ore (drill hole BCX-1). A comparison of these relationships is summarized below:

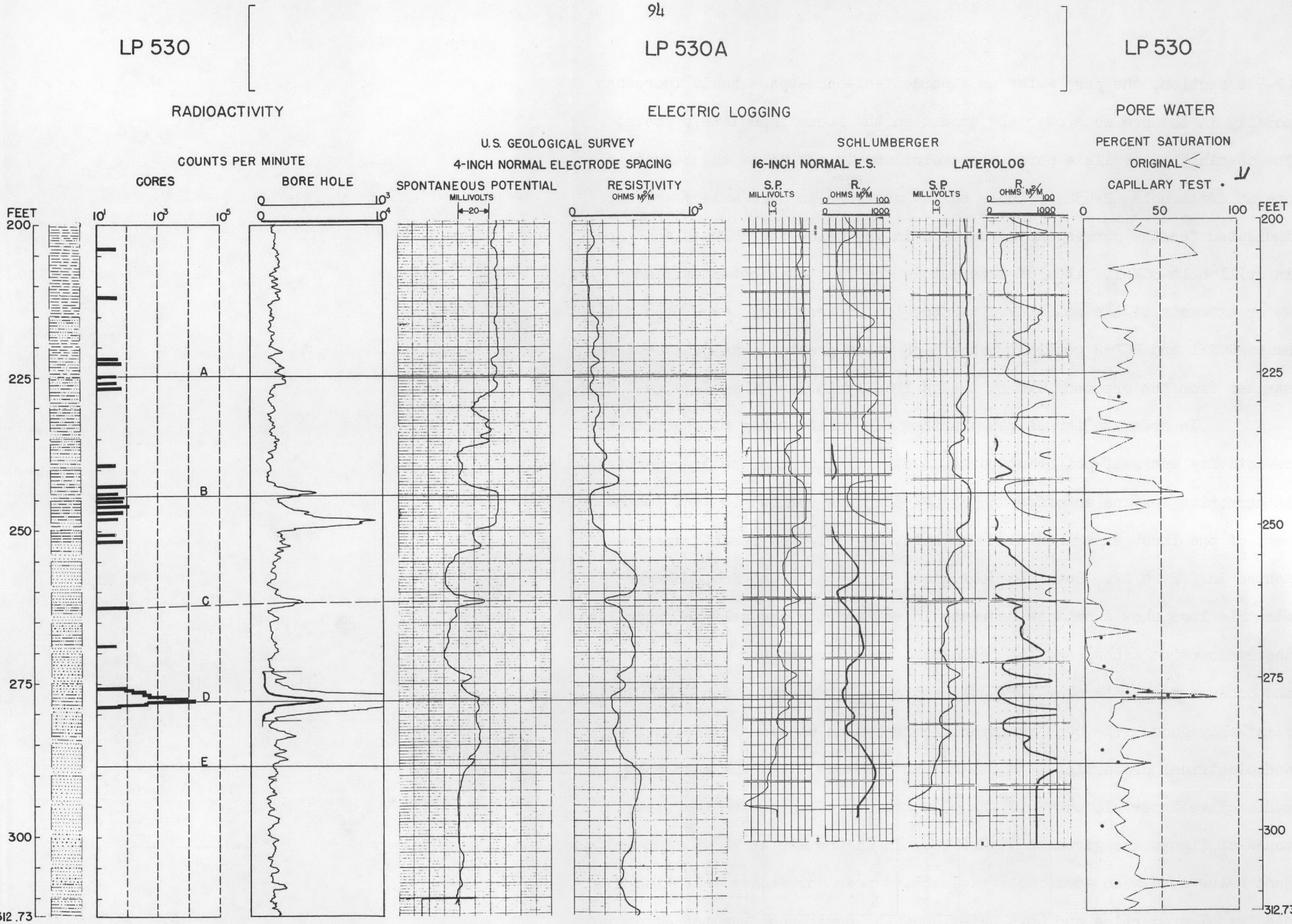
Table 3.--Data from Long Park drill hole LP-530

Drill hole	Interval referred to ore zone	Number of Samples	Water content, percent of pore space	Permeability, dry air, millidarcies	Soluble solids assigned to pore water, ppm
LP-530	0-24' above	24	7.3	343	350,000
	2.9' ore zone	8	46.4	174	47,300
	0-34' below	35	29.1	479	75,300
BCX-1	0-23' above	23	39.2	0.07	375,000
	3.6' ore zone	10	55.7	0.18 (8 samples)	397,000
	0-25' below	23	68.8	0.02 (20 samples)	335,000

As the BCX-1 samples from the ore-bearing sandstone are much less permeable than the LP-530 samples, the average pore size is less and the pore water content throughout the "sandstone" is greater. But, as in the

LP-530 section, the pore water on a percent-of-pore-space basis increases notably in the ore zone over the amount in the rocks immediately above. The possibly more dilute pore water solutions in and below the carnotite ore in drill hole LP-530 (soluble solids assigned to pore water) are not indicated for the corresponding section in and below the "blue-black" ore in drill hole BCX-1. Also of interest is the fact that hot-distilled water extracts of the soluble salts from the Bitter Creek cores from drill holes BCX-1 and BCX-2 generally show a pH value greater than 8, except in samples from the ore zone, where the pH locally is less than 7.

In order to investigate further the relationship of electrical resistivity and self-potential to radioactivity and other core properties in carnotite terrane an offset hole, LP-530A, was drilled 10 feet southwest of the first experimental drill hole, LP-530. The results are presented in figure 22. Both the Geological Survey and the Schlumberger electric logs show a notable decrease in resistivity and self-potential in the radioactive zones, and the reciprocal relation between resistivity of the Schlumberger laterolog (LP-530A) and pore water saturation (LP-530) is remarkably good. The best reciprocal correlation between radioactivity and electrical properties is shown by the ore zone D and the next most radioactive interval, zone B. The eU_3O_8 values of these and the other zones of figure are given in figure 20. In figure 22, at 283.5 feet and just below zone D an additional radioactive peak correlates well with the electrical properties and pore water, but the core count was not determined. Zone E is anomalous. Another pore water maximum is present here, but it coincides with a resistivity maximum rather than a minimum. Zone E may represent the top of an interval in the sandstone containing pore water of



1/ **Core saturated with water, then desaturated through semi-permeable membrane under 100 psi air pressure.**

Figure 22

RELATIONSHIP OF RADIOACTIVITY AND ELECTRICAL PROPERTIES IN CARNOTITE TERRANE, LONG PARK AREA, MONTROSE COUNTY, COLORADO

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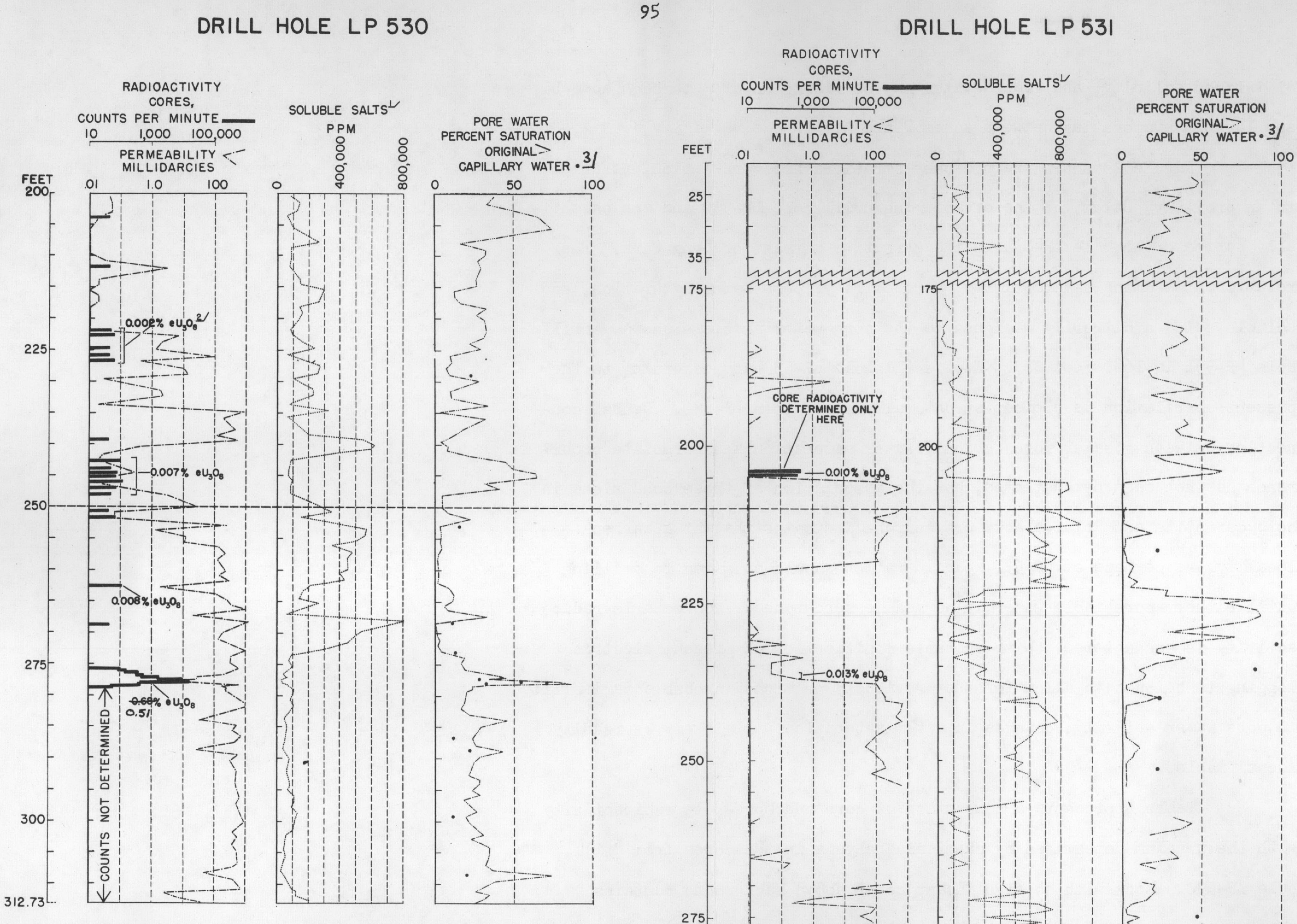

1/ ARBITRARILY ASSIGNED TO PORE WATER

2/ ALL U_3O_8 DETERMINATIONS FROM GAMMA-RAY LOG

3/ **Core saturated with water, then desaturated through semi-permeable membrane under 100 psi air pressure.**

Figure 23 COMPARISON OF PHYSICAL PROPERTIES OF CARNOTITE-BEARING ROCKS, LONG PARK AREA, MONTROSE COUNTY, COLORADO

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diminished salinity, and ground water may be rising upwards through zone D and largely evaporating between zones D and C.

Figure 23 shows the presumed stratigraphic correlation, referred to an arbitrary datum, of the ore-bearing drill hole LP-530 and the essentially barren drill hole LP-531 in the carnotite terrane of Long Park. The relationships among radioactivity, permeability, pore water saturation, and soluble salts arbitrarily assigned to the pore water also are shown. Drill hole LP-531 is 1680 feet S. 74° E. of drill hole LP-530 and according to the present correlation is 85 feet structurally lower than LP-530. Causal connection between greater pore (ground) water saturation and carnotite occurrence has not been demonstrated, but the association of these conditions in both carnotite and "blue-black" ore terrane indicates that at a barren locality, as perhaps at LP-531, consideration should be given to drilling until either appreciable water in permeable sandstone or appreciable radioactivity is encountered. With suitable modification of present electric logging techniques to allow for the previously mentioned probable variability in pore water salinity, changes in water saturation will likely be readily identifiable.

Table 4 presents a comparison of core and bore-hole radioactivity with the uranium determined by chemical analysis in the cores from drill hole LP-530. Rock with no significant count above background contains about 0.001 percent U, but rock with only 0.0013 percent U (zone B) shows detectable anomalous radioactivity both in the cores and bore hole. The eU_3O_8 may exceed the U by about 30 percent (zone D).

The Eastern Regional Laboratory of the U. S. Bureau of Mines, College Park, Maryland, has related the petrography of cores from drill

Table 4.--Comparison of core and bore-hole radioactivity with uranium in cores, drill hole LP-530

Zone, figure	Sample numbers	Core interval, feet	Radioactivity: Bore-hole, percent eU_3O_8	Radioactivity: Core, counts per minute	Uranium, chemical, percent
A	24, 25, 27-29	221.31 to 226.96	0.002 (1.45')	44 ± 28	not determined
-	37, 39	233.00 to 235.88	Barren		0.001 to 0.0009
B	47, 48-53 56, 57	242.02 to 252.04	0.007 (5.57')	43 ± 28 to	
				118 ± 30	
				118 ± 30	0.0028
				66 ± 29	0.0013
C	69	262.04 to 263.00	0.008 (1.07')	112 ± 30	not determined
D (ore only)	85	276.73 to 277.66	0.51 (.83')	1,928 ± 52	0.046
				10,097 ± 104	0.26
				17,418 ± 132	0.96
	Weighted average, Zone D:		0.51 (83')		0.38 (.83')

holes LP-530 and LP-531 to previous dynamic tests of elastic constants. A partial summary of the Bureau's and additional data is presented in table 5.

Specimens LQ.2 and LQ.11 are described as friable sandstone and specimen LQ.5 is designated friable silty sandstone. These samples are composed mainly of quartz particles with some chert, feldspar, calcite, and rock fragments. A few of the quartz particles show some overgrowth and minor embayment. However, the bonding in general is poor. Speciments LQ.6 and

Table 5.--Data from core holes LP-530 and LP-531

	Drill hole LP-530					Drill hole LP-531	
Bureau's Sample No.	LQ.8	LQ.6	LQ.5	LQ.2	LQ.11	LR.1	LR.3
Depth, feet	203.98 to 204.96	220.34 to 221.31	229.90 to 230.83	258.42 to 289.30	279.38 to 280.23	36.03 to 37.00	271.07 to 272.01
Drilling fluid	Air	Air	Air	OBM 1/	OBM 1/	Air	Air
Geol. unit	B.B.2/	B.B.	B.B. (SW?)	SW	SW	B.B.	SW
Bar velocity, ft/sec							
Longitudinal		5,500	5,600	7,500	6,000	7,700	10,000
Torsional			5,400	6,400	5,800	5,900	6,400
Permeability3/, Millidarcies		~.01	~.1	~100	~500	~4.0	~10?

1/ OBM = Oil-base mud

2/ B.B = Brushy Basin member of Morrison formation
SW = Salt Wash member of Morrison formation

3/ Estimated from vertically adjacent samples

LQ.8 are described as argillaceous sandstone composed essentially of subangular quartz particles with a minor amount of feldspar in a matrix of calcite, sericite, limonite and clay. Specimens LR.1 and LR.3 are described as sandstone similar to LQ.2 and LQ.11 but the quartz particles show much more resorption and overgrowth and consequently better interlocking. Thus, on the basis of those samples the essentially barren drill hole LP-531, in the ore-bearing sandstone unit of the Salt Wash member shows tighter bonding and the higher longitudinal velocity of 10,600 ft/sec, whereas this unit in the carnotite-type drill hole LP-530 shows looser bonding and longitudinal velocity of 6,000 to 7,500 ft/sec. Possible distinction between ore-bearing and barren ground by means of well velocity shooting is indicated.

Black Hills, S. Dak.

by G. B. Gott, Henry Bell, III, N. P. Cuppels, E. V. Post and R. W. Schnabel

Geological investigations

Investigations during the past six months as part of the southern Black Hills project consisted of areal mapping (scale 1:7200), of approximately 140 square miles, geochemical and detailed geological investigations covering about one-sixth square mile, and geologic mapping of the Gould and Livingston mines. Areal mapping of the Edgemont, Edgemont NE, and Minnekahta quadrangles was completed, and mapping of the Flint Hill quadrangle is about 80 percent complete. (See figure 24.)

As the past summer's field work of both the geological and geochemical investigations has been completed only recently a statement of the results must await compilation and evaluation of the field data and receipt of analytical data. The preliminary data, however, indicate that structure, lithology, and perhaps chemical environment were important factors in the localization of uranium-vanadium deposits. A summary of the relationships between these factors and the ore deposits follows:

Structure

The geologic mapping completed in this area during 1953 indicated a relationship between specific parts of folded structures and ore deposits.

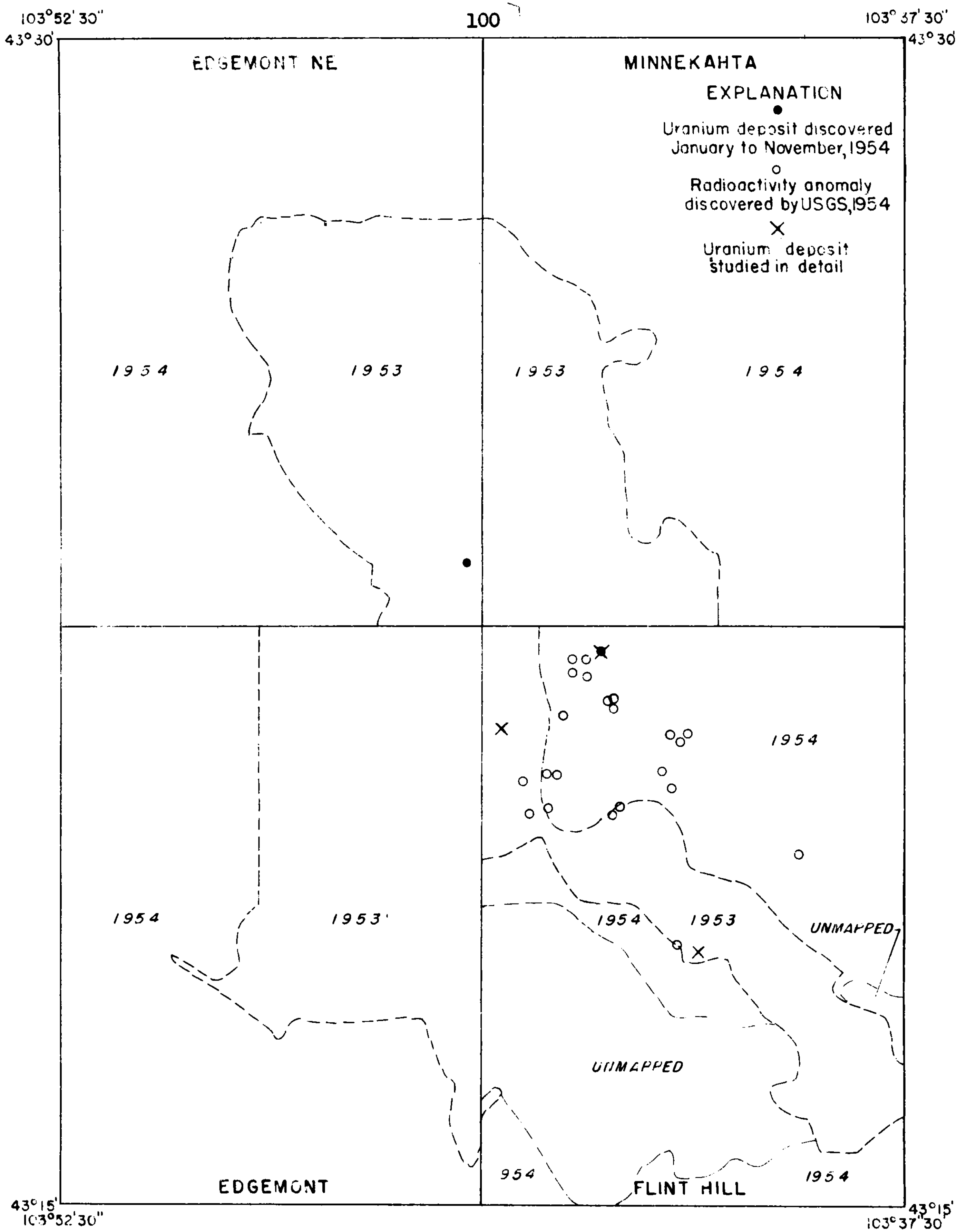

FIGURE 24 INDEX MAP SHOWING AREAS MAPPED AND DEPOSITS STUDIED, JUNE TO NOVEMBER, 1953, AND JUNE TO NOVEMBER, 1954, FALL RIVER COUNTY, SOUTH DAKOTA

0 1 2 MILES

To test the validity of this relationship the AEC in May 1954 drilled a few holes on what was considered a favorable structure in the "East Red Canyon Area". Approximately five tons of ore per foot of drilling was discovered. Geologic mapping during the past 6 months has largely supported the concept that structure was a factor in the localization of the ore deposits. At the present stage of development most of the mined and known minable deposits are in three areas: (1) The large structural terrace in the northwestern part of the Flint Hill quadrangle, the southwestern part of the Minnekahta quadrangle, and the southeastern part of the Edgemont NE quadrangle. The largest known deposits of the district are in this area. (2) The relatively small structural terrace between Craven and Coal Canyons on which most of the Fall River deposits have been found. Most of the ore mined to date came from this area. (3) The Lakota deposits of upper Craven Canyon, North Long Mountain, and upper Red Canyon. Many of these deposits are obviously within areas where the sandstones have been locally flattened. The structures are small and the production has been negligible.

Other types of structure, such as faults and joints, may have influenced the localization of some deposits. The amount of ore localized in this type of structure is small, but in some places, as in the Lion No. 1 mine, the Livingston mine, and a small prospect near the Gould mine, the carnotite is concentrated principally along the joints.

Channel sandstones

Mapping of the lithology in the Inyan Kara group of formations has resulted in the definition of a number of elongate bodies of sandstones, most of which appear to represent filled stream channels. These channels vary in width from less than one mile to perhaps as much as six miles and occur throughout the Fall River, Fuson, and Lakota formations.

The largest of the probable channels are shown on figure 25. Channel I includes the thick lower Lakota sandstones such as those in Chilson, Craven, and Red Canyons. These sandstones apparently represent the fill that was deposited in a broad valley from which the basal Lakota carbonaceous siltstones had been partly to completely removed.

Channel II is exposed discontinuously from Pilger Mountain to Red Canyon, and it may continue eastward to the Gould lease in the northwest part of the Flint Hill quadrangle. In the Coal Canyon area the sandstone is cemented with carbonate. The sandstone generally is medium-to coarse-grained and is non-carbonaceous.

Channel III appears to represent the sandstone fill in a drainage system that had largely removed a series of interbedded sandstones, carbonaceous siltstones, and mudstones, which in the area to the west contain producing ore deposits. The channel sandstone is the principal cliff-forming member of the Fall River.

The boundaries of Channel IV in the Fall River sandstone are as yet ill-defined; however, the probable position of this channel has been plotted by outlining the area containing an abnormally thick section of Fall River sandstone with little or none of the various types of mudstones common in the Fall River in adjoining areas. Some evidence of truncation of older sediments by the sandstones included in this channel has been observed along the eastern edge of the Flint Hill quadrangle. The wider channels are complex in character, being composed of several types of cross-bedded sandstone interbedded with lenses of mudstone and siltstone.

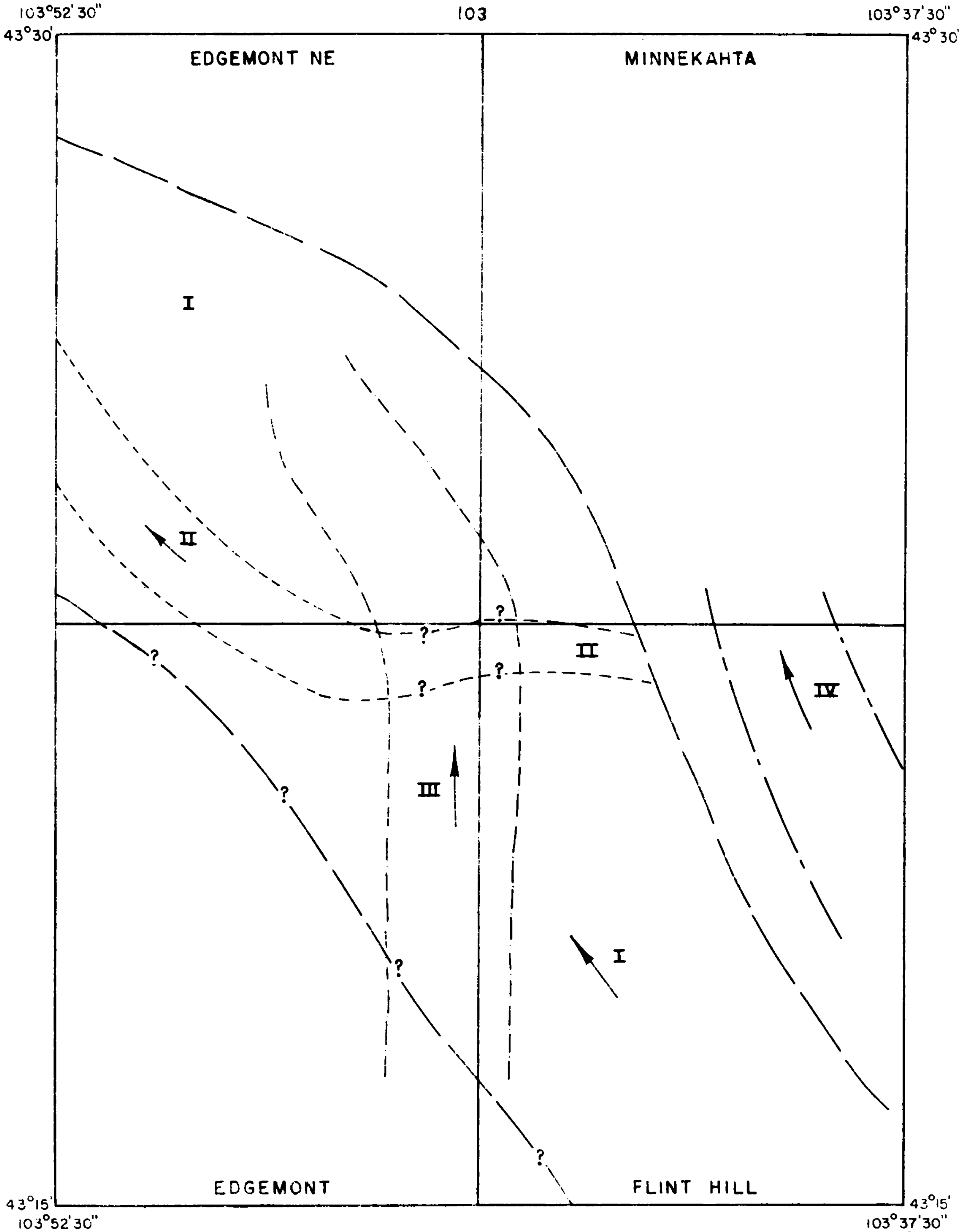

FIGURE 25 PROBABLE DISTRIBUTION OF MAJOR CHANNELS IN THE INYAN KARA GROUP, FALL RIVER COUNTY, SOUTH DAKOTA

0 2 MILES

Some of these cross-bedded sandstones truncate the older rocks within the channel. The smaller channels appear to be less complex lithologically and some have more sharply defined borders. It seems likely that in some areas the change from massive channel sandstone to mudstone is gradational with increasing amounts of siltstone and clay away from the axis of the channel, whereas in other areas the change is abrupt, because of truncated thin-bedded sandstone and siltstone or mudstone.

The Gould Lease

A detailed study of the Gould Lease was begun in May 1954 to investigate factors controlling deposition of carnotite ore, to evaluate the effectiveness of geochemistry and thermoluminescence as guides to ore when combined with a knowledge of stratigraphy, lithology, and structure of a known ore body, and to describe in detail one of the most productive uranium mines in the southern Black Hills. The Gould Lease is in the SE$\frac{1}{4}$ sec. 11, T. 8 S., R. 3 E. All production has come from underground workings, which consist of a series of connecting drifts, with a combined length of 430 feet.

Surface geology of an area 1440 feet long and 640 feet wide in the vicinity of the Gould Lease is being mapped on a scale of 1 inch to 40 feet. The Pabst No. 3 claim, which has been mapped at the same scale, adjoins the Gould Lease on the northeast. In addition to surface mapping, the underground workings are being mapped at a scale of one inch to 10 feet as the ore is mined. Eighty percent of the surface and underground mapping has been completed. Underground mapping will continue until the ore is exhausted. As data become available, structure contour maps, isorad maps, isopach maps of the ore, and geologic sections are constructed. Concurrent with the underground mapping, samples are taken for permeability and thermoluminescence studies and for chemical analyses. Fifty-four samples have been taken of rock units associated with the ore. Additional data on the ore are being compiled from lithologic and radioactivity logs of 57 wagon drill holes and current drilling in the area by the Rudman Oil Co., the AEC, and the mine operators.

Regional mapping in the area by the USGS indicates that the ore deposit is 60 to 70 feet above the base of an elongate, easterly-trending body of sandstone in the lower Fall River sandstone (Channel II, fig. 25). The host rock is generally a medium- to coarse-grained non-carbonaceous sandstone. In some places, however, the undulate upper surface of the ore extends into an overlying clay-gall conglomerate. Although the ore body has not been adequately outlined by drilling or mining, it seems to have an easterly trend and has an average thickness of at least 3 feet. Although a set of northwesterly-trending master joints appears to have controlled much of the mineralization, many of the faces and walls of the mine show an irregular distribution of the ore not directly associated with the structure. Major shifts in the trend of the ore occur in faces of massive sandstone where there are no apparent changes in lithology or structure.

Radioactivity survey

A radioactivity survey of part of the Flint Hill quadrangle detected 26 new anomalies (fig. 24). Some of these are more encouraging than others. Several of the anomalies were in areas of thin-bedded sandstone and siltstone--a lithology similar to that containing some of the larger Fall River ore deposits of dark uranium and vanadium minerals in the Edgemont NE quadrangle. This area of thin-bedded sandstone and siltstone parallels one of the channel sandstone bodies which contains the carnotite ore deposits of the Lion No. 1 claim and the Sheep Canyon claims. Several of the anomalies found suggest that one of the smaller channel sandstones might be favorable for deposits of the type now being mined on the Gould lease.

Geochemical investigations

Since July 1954 study has been made of the value of geochemical methods of uranium prospecting when combined with detailed geologic mapping. Long Mountain was selected as the site for study because of the abundant information available on the subsurface geology of an area including several small ore bodies discovered by AEC exploratory drilling.

Field work completed during the summer of 1954 includes the construction of a geologic map of an area 1200 feet by 1800 feet in the NE¼ sec. 30, T. 7 S., R. 3 E., at a scale of one inch to 100 feet; the compilation of data needed to construct isorad maps, geologic sections, and structure contour maps; the lithologic and radioactivity logging of cores from 74 diamond drill holes; the sampling of every lithologic unit in each drill core for geochemical analysis; the selection of rock specimens from barren and mineralized parts of the core for thin section study; the collection at 100-foot intervals throughout the map area of soil samples for geochemical analyses; and the collection of selected rock specimens for thermoluminescence studies.

Devils Tower, Wyoming and Montana

by C. S. Robinson, W. J. Mapel, and M. H. Bergendahl

The Devils Tower area (fig. 26) includes parts or all of the Newcastle, Moorcroft, Rozet, Devils Tower, Bertha, and Aladdin 30-minute quadrangles in Wyoming, and the southern part of the Broadus, Ridge, and Ericson 30-minute quadrangles in Montana. Most of the area was mapped by W. W. Rubey and others of the Geological Survey from 1922 to 1924, but the maps were not published (fig. 27). The southeast quarter of the Devils Tower quadrangle was mapped by the authors in 1954 and geologic mapping of the area is now complete. Work remaining to be done consists of checking the earlier work of Rubey and others, compiling the map and stratigraphic sections, and preparing a descriptive text. As the entire area has not been examined by the authors nor has all of the earlier work been compiled, only a brief description of the general geology can be given at this time.

Exposed sedimentary rocks in the area have an aggregate thickness of about 10,000 feet and range in age from Triassic to Recent. The sequence includes rocks of both marine and non-marine origin, the latter consisting mostly of sandstone and shale. The rocks may be divided into 33 units, exclusive of surficial deposits of Quaternary age, as shown in table 6. All formations are essentially concordant in dip except for the White River formation of Oligocene age and the deposits of Quaternary age, which overlap the older rocks.

The three formations in the Inyan Kara group, the Lakota, Fuson, and Fall River, are difficult to map or correlate over any great distance because the lithology, especially in detail, is extremely variable along the strike and dip. In most areas the group may be divided into an upper sandstone unit, a middle shale unit, and a lower sandstone unit.

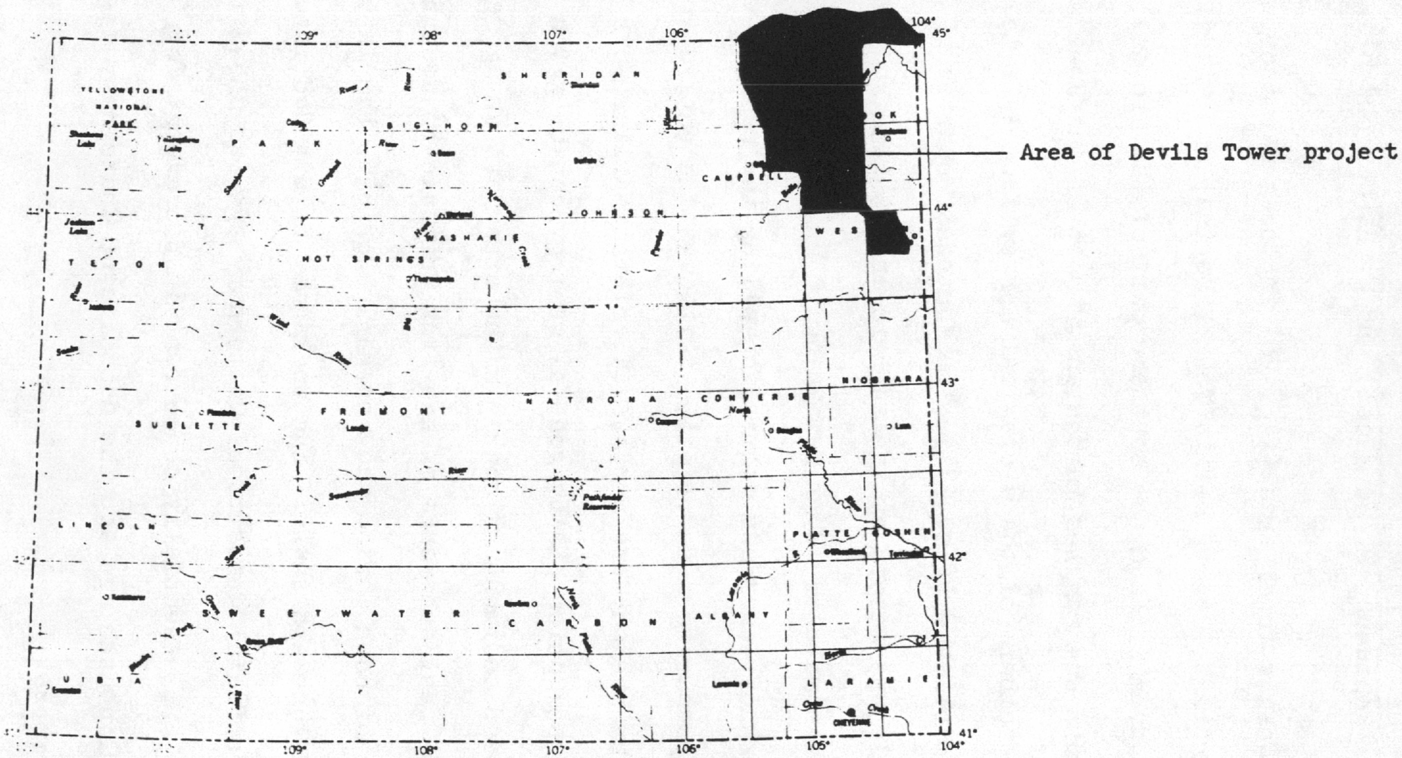

FIGURE 36--INDEX MAP OF WYOMING, SHOWING LOCATION OF DEVILS TOWER PROJECT

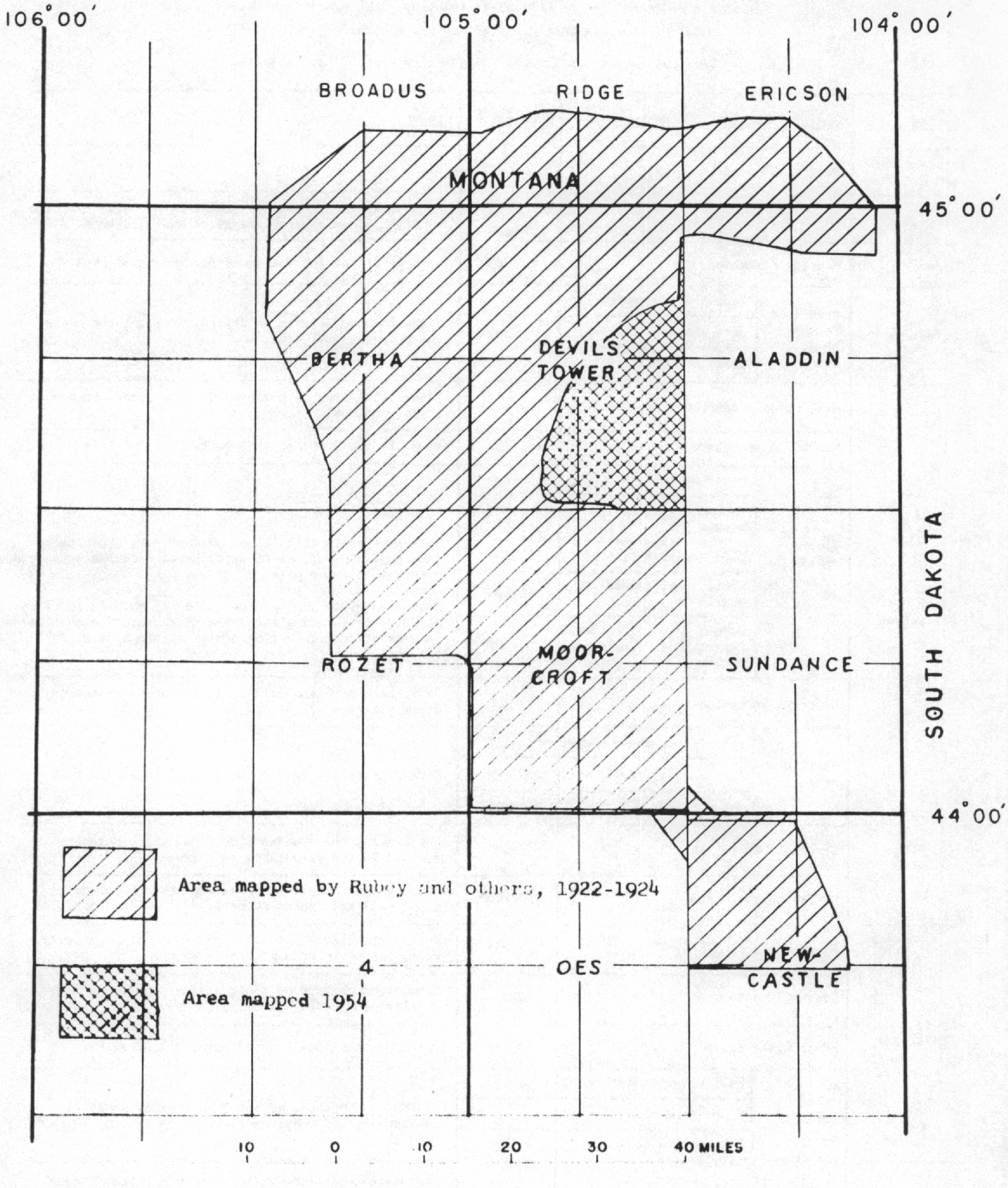

FIGURE 27--DEVILS TOWER PROJECT, WYOMING AND MONTANA

Table 6.—Generalized section of sedimentary rocks exposed on the northwestern flank of the Black Hills

(Adapted in part from U. S. Geol. Survey Prof. Paper 165A)

Series	Group, formation, and member		Thickness (feet)	Description
Pleistocene and Recent	Surficial deposits			Silt, sand, and gravel
	Unconformity			
Oligocene	White River formation		0-150	Light-gray coarse-grained sandstone at base, overlain by light brownish-gray claystone and siltstone.
	Unconformity			
Eocene	Wasatch formation		100±	Drab sandstone and shale and numerous coal beds.
Paleocene	Fort Union formation	Tongue River member	1600±	Light-colored massive sandstone, drab-colored shale, and numerous coal beds.
		Lebo shale member		
		Tullock member		
Upper Cretaceous	Hell Creek formation		850-1150	Alternating beds of massive sandstone, dark-colored shale, and coal.
	Fox Hills sandstone		150-250	Brownish sandy shale, siltstone, and sandstone
	Pierre shale	Upper member	150-250	Dark-gray shale with impure bentonite in upper part; limestone concretions in upper part, siderite concretions in lower part. Groat sandstone member consists of as much as 150 feet of ferruginous and glauconitic fine-grained sandstone; is present only in northern part of the area.
		Monument Hill bentonite member	150±	
		Middle member	500-800	
		Mitten black shale member	150-200	
		Gammon ferruginous member / Groat sandstone member	800-1000	
	Niobrara formation		125-200	Gray chalk marl and calcareous siltstone weathering light yellow
	Carlile shale	Sage Breaks shale member	250-350	Dark-gray shale, more or less sandy in middle part
		Turner sandy member	150-200	
		Unnamed member	150-200	
	Greenhorn formation		50-350	Chalk marl, thin-bedded limestone, and light-gray shale. Varies from place to place.
	Belle Fourche shale		350-1000	Black shale with concretions and bentonite beds in upper half and lowermost part.
Lower Cretaceous	Mowry shale		125-225	Dark-gray siliceous shale, weathering light silvery gray; many thin beds of bentonite.
	Newcastle sandstone		0-75	Discontinuous beds of sandy shale, sandstone, impure lignite, and bentonite
	Skull Creek shale		175-275	Black shale with a few ferruginous concretions
	Inyan Kara group	Fall River sandstone	50-150	Discontinuous beds of sandstone, sandy shale, siltstone, and conglomerate.
		Fuson formation	100±	
		Lakota sandstone	25-150	
	Unconformity?			
Upper Jurassic	Morrison formation		0-250	Variegated claystone with a few thin discontinuous beds of sandstone and limestone
	Sundance formation	Redwater shale member	300-375	Mostly alternating yellowish-gray sandstone and greenish-gray shale; a few thin beds of gray limestone in upper part. Lak member is red or light yellowish-gray calcareous sandstone
		Lak member		
		Hulett sandstone member		
		Stockade Beaver shale member		
		Canyon Springs sandstone member		
	Unconformity			
Middle Jurassic	Gypsum Spring formation		0-125	Massive gypsum at base overlain by interbedded gypsiferous red claystone and cherty gray limestone.
	Unconformity			
Triassic	Spearfish formation		600±	Red shale, siltstone, and sandstone. beds of massive gypsum in lower part.

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Igneous rocks, which crop out principally in the Devils Tower quadrangle, comprise only a very small percentage of the total area. They occur as sills, dikes, and small plugs or stocks and range in composition from monzonite to feldspathoidal syenite. In texture they are, in general, porphyries with a fine-grained to aphanitic groundmass.

The major structural feature is a monocline that borders the Black Hills uplift on the west and north. The dips range from 2 to 4 degrees on either limb of the monocline but steepen sharply to as much as 60 degrees in a belt 5 to 10 miles wide extending from the northeastern quarter of the Newcastle quadrangle, northwestward across the Moorcroft quadrangle, and northward through the western half of the Devils Tower quadrangle to within about 5 miles of the Wyoming-Montana state line. Many small folds are superimposed on the regional monocline. These folds are most numerous and better developed in a belt that parallels and lies east of the sudden steepening of the dip of the regional monocline in the Newcastle, Moorcroft, and the southern part of the Devils Tower quadrangles and extends across the northern part of the Devils Tower and the northern part of the Aladdin quadrangles.

Few faults occur in the mapped area with the exception of two small areas in the Devils Tower quadrangle, one in the north-central part and one in the south-central part. The faults are, in general, normal faults with displacements of less than 50 feet, and are less than a mile long.

The uranium occurs in carnotite-type sandstone deposits. The ore deposits mined to date are in the north-central part of the Moorcroft quadrangle and in the west-central part of the Devils Tower quadrangle. They occur in a belt of radioactivity anomalies 10 to 20 miles wide that extends from the south-central part of the Moorcroft quadrangle northward to the west-central part of the Devils Tower quadrangle and northeastward across the north-central part of the Devils Tower and Aladdin quadrangles. The belt of anomalies coincides in part with the belt of more intense folding on the eastern limb of the regional monocline.

Although radioactivity anomalies have been reported throughout the stratigraphic section, the ore deposits are restricted to the Inyan Kara group. This group is exposed throughout most of the eastern half of the mapped area, forming broad almost level divides between major drainage basins. Most of the ore mined has been taken from the Fall River sandstone; one deposit has been mined from the Lakota sandstone and one from a sandstone in the Fuson shale.

Dripping Spring, Arizona
by H. C. Granger and R. B. Raup, Jr.

The Dripping Spring quartzite of pre-Cambrian age is exposed over parts of a 7,000-square-mile area in southeastern Arizona. It is a formation within an essentially conformable series of limestones, quartzites and conglomerates called the Apache group.

Uranium deposits have been known in the Dripping Spring quartzite since early 1950, and reports by the USGS and AEC have described some of the deposits (RMO-679, 1950; TEM-210, 1951; USGS Circ. 137, 1951; RME-2003, 1953; RME-2005, 1953). Prospecting activity has been intensive since February 1954 and many new deposits have been found. Ore-grade material is being mined from at least six different deposits, and several others probably will be in production shortly. The ore is presently being stockpiled.

Field work on the Dripping Spring project began in early July 1954 and continued until December. During this period the project personnel studied mainly the lithology and ore deposits in the Dripping Spring quartzite in the McFadden Peak, Blue House Mountain, and Rockinstraw 15-minute quadrangles in the Sierra Ancha Range north of Globe.

At this time no laboratory work has been conducted on samples collected during field work. This report briefly describes the lithology of the Dripping Spring quartzite and the generalized field relationships of the deposits. Although no individual deposits will be described, the information given will apply to the majority of the deposits studied.

Associated rock types

The generalized columnar section for the Sierra Ancha region north of Roosevelt Lake in Gila County, Ariz., is as follows:

Age	Rock type	Thickness (feet)
Tertiary and Quaternary	Gravel and sand	
Cambrian	Troy sandstone	500
	Unconformity	
Younger pre-Cambrian (Apache group)	Vesicular basalt flow	0-75
	Mescal limestone	225-400
	Dripping Spring quartzite	450-700
	Barnes conglomerate	5-50
	Pioneer formation	150-250
	Scanlan conglomerate	0-30
	Unconformity	
Older pre-Cambrian	Granite and schist	

Rocks of the Apache group are extensively intruded by sills and dikes of diabase. The diabase generally is considered one unit, but is known to consist of several separate intrusions distinguished only by chilled borders where they are in contact with one another.

Dripping Spring quartzite

The Dripping Spring quartzite may be conveniently divided into an upper and lower member. The lower member, which is gradational into the underlying Barnes conglomerate, is composed of about 300 feet of fine- to very fine-grained thick-bedded obscurely cross-laminated quartzite. The lower part is commonly light red to reddish orange and is highly arkosic. It grades upward into a grayish-pink to very pale orange, relatively pure quartzite. No uranium deposits have been found in the lower member although local concretions and indurated mudstone lenses are slightly radioactive.

The upper member is about 300 feet thick. It is predominantly clayey, silty, and very fine-grained and contains cross-laminated beds in the lower and upper parts. It is composed essentially of three units. The lower unit consists of alternating platy and more thickly-bedded, light grayish-red and orange quartzites and indurated siltstones. It is as much as 100 feet thick and grades into the middle unit, which is composed of about 100 feet of light-to dark-gray thinly laminated indurated siltstone. The middle unit has a platy appearance on weathered surfaces and is stained and coated with red to black iron and manganese (?) oxides. Just beneath the weathered surface the rock is commonly bleached for one inch to several feet. The upper unit is generally very fine-grained, with thinly laminated, light-colored quartzite near the top. The upper 15 to 40 feet is locally platy and similar to the middle unit.

Greenish and reddish mudstone beds of the lower Mescal limestone conformably overlie the upper unit.

All known uranium deposits in the Dripping Spring quartzite are in the lower and middle units of the upper member, those in the lower unit being confined to the upper or gradational part.

The middle unit of the upper member commonly contains much finely disseminated pyrite. The characteristic dark-gray color in the fresh rock may be caused by this fine pyrite or may be related to the carbon or manganese content.

The entire upper member is everywhere abnormally radioactive. Its radioactivity of .03-.05 mr/hr contrasts with .02-.04 mr/hr for the lower member and about .01-.015 mr/hr for the Mescal limestone and diabase.

Spatial relationships of the uranium deposits

Most of the known uranium deposits in the Dripping Spring quartzite have four characteristics in common:

1. They are restricted to the middle unit of the upper member of the Dripping Spring quartzite or to the gradational part of the lower unit just below. They are therefore restricted to a vertical distance of less than 150 feet.
2. They are controlled by fractures that trend either N. 10°-30° E. or N. 65°-85° W., although some disseminated ore minerals are in the wall rocks adjacent to the fractures. Statistical studies throughout the Sierra Anchas show that these are two of the strongest joint trends in the region.

3. The more promising deposits are near strong structures that are contemporaneous with or pre-date the diabase intrusions.

4. All deposits are near diabase, and some of the more promising deposits are near a coarse-grained syenitic or granophyric differentiate of the diabase.

Mineralogy

In some deposits the fractures are filled with as much as 2 inches of gouge, gossan, sulfides, and locally vein quartz. In others the fractures are so tight that only disseminated minerals are visible. In unoxidized parts of the better developed deposits, pitchblende, pyrite, chalcopyrite, galena, and rarely sphalerite are present. In the oxidized parts of the deposits the uranium minerals are metatorbernite, autunite, uranophane, bassetite, and perhaps other minor minerals. These are associated with hydrous iron oxides, gypsum, and more rarely malachite, azurite, and fluorescent opal.

Size of the deposits

Most deposits appear to extend through a stratigraphic interval of from 6 inches to 20 feet. The rock adjacent to the fractures may be abnormally radioactive for several hundred feet but, unless the fractures are very closely spaced, the ore width is commonly less than 5 feet. The length over which a fracture may be mineralized varies from a few feet to over 150 feet.

Conclusions

The intimate association of pitchblende and sulfides in the primary parts of these deposits and the intense oxidizing and leaching conditions to which they have been exposed during weathering suggest that most of the deposits increase in grade with depth. This has already been demonstrated in several deposits. The general shape of the deposits provides small targets for exploration by drilling.

Powder River Basin, Wyoming

by W. N. Sharp, E. J. McKay, and F. A. McKeown

Geologic mapping of the Wasatch formation (Eocene) in the Pumpkin Buttes area was completed and the greater part of the eight 7½-minute quadrangles in the Power River Basin has now been mapped (fig. 28). Uranium deposits at several mine areas were mapped by plane table and sketch methods. Soil samples at 50-foot intervals were collected at one mine locality before mining was begun. Water samples were taken throughout the area.

To obtain guides for uranium exploration, lithologic relations within the Pumpkin Buttes area of uranium deposits were compared with those in adjacent barren areas.

Interpretation of a lithofacies map of the Wasatch formation and orientation of sandstone structures indicate that the sediments comprising the formation were derived from the southeast. The principal Eocene stream drainage and areas of sandstone deposition in the Wasatch include the Pumpkin Buttes area and larger contiguous areas to the southeast, east, northeast, and north. Flood plain deposits of fine-grained clastics, small limestone lenses, and coal occupy a large area northwest of the area mapped, as well as the eastern and western border zones of the Wasatch outcrops in the basin.

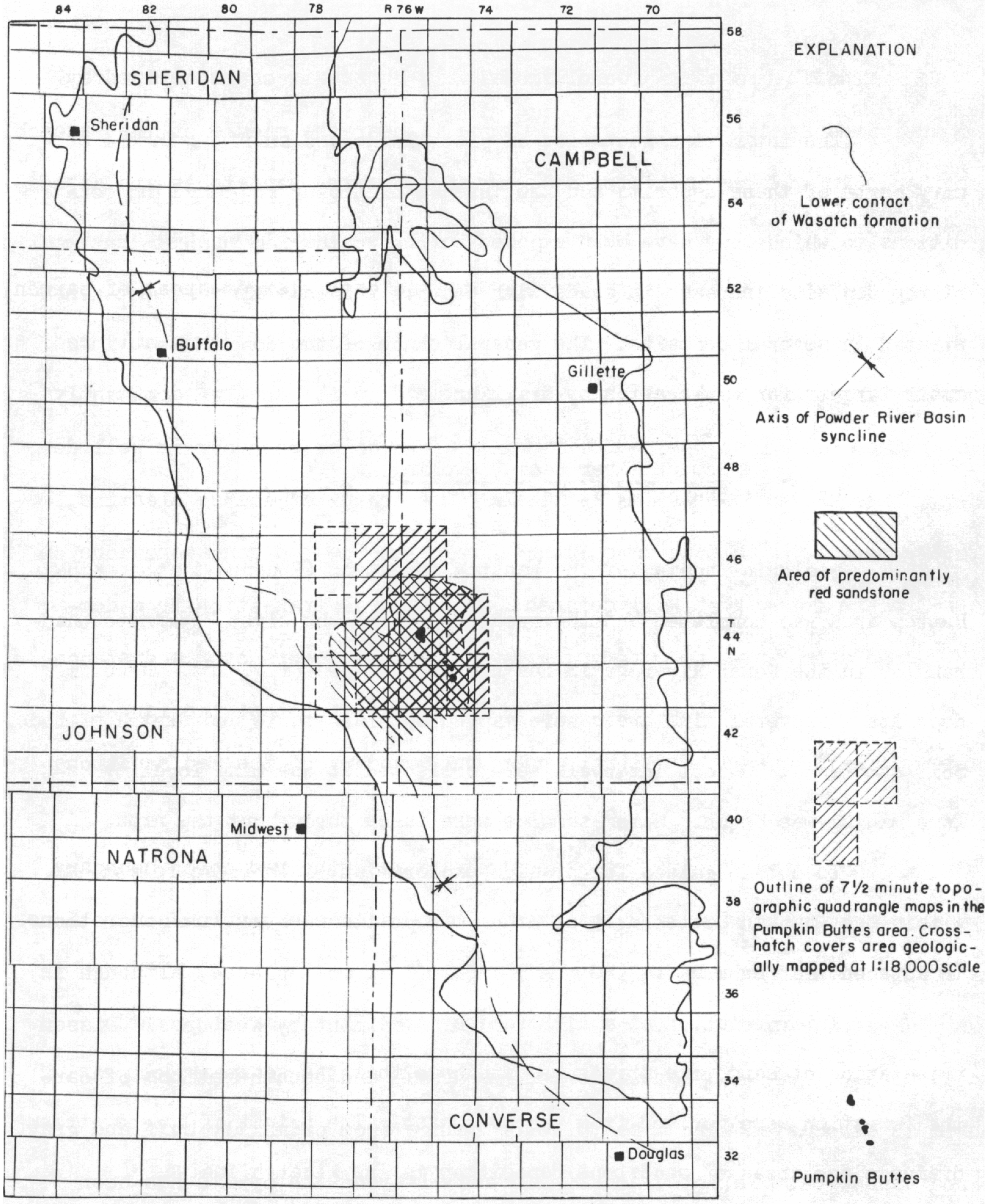


FIGURE 28—GEOLOGIC MAP OF THE POWDER RIVER BASIN, WYOMING, SHOWING KNOWN EXTENT OF RED SANDSTONE AND STATUS OF GEOLOGIC MAPPING

A definable area around the Pumpkin Buttes is characterized by dominantly red sandstone lenses; this zone is near the middle of the Wasatch. Areal geologic mapping indicates that uranium-bearing sandstones are associated with this zone of interbedded, dominantly red sandstone lenses and claystone strata. On the north, northeast, and east, larger areas of barren, buff and gray sandstones border the Pumpkin Buttes area of dominantly red sandstones. On the west, red sandstones extend to the area of dominantly fine-grained clastics; on the northwest the red color boundary is well defined although coarse clastics continue. The amount of coarse clastics, however, decreases in that direction. Limits of the red sandstone zone on the south are not as yet well defined. The lateral transition from dominantly red sandstones to buff and gray sandstones occurs over a distance of about one to five miles. Perhaps it is significant that the larger uranium deposits mined to date are near the boundary of the red sandstone area.

Locally, in individual sandstone lenses, the red color boundary transects primary sedimentary features. Iron-manganese-uranium concretions are scattered erratically in the red sandstone at most places, although in some places they are associated with primary sedimentary features. Disseminated uranium ore with some iron and manganese and concentrations of carbonate is associated with a sharp color change from primarily buff and gray to red sandstone. Relict uraninite in association with pyrite has been discovered in disseminated-type ore bodies at two mine localities.

Crooks Gap area, Fremont County, Wyoming
by J. G. Stephens

Radioactive anomalies were discovered in the Crooks Gap area in February 1954 by private aircraft reconnaissance. These anomalies resulted in the filing of the Sno-ball claims, the only ones from which ore has been shipped to date. The most active area of prospecting is centered along the eastern side of the gap near the base of Sheep Mountain.

Field work was begun on August 12 and recessed on October 28. A geologic map covering 53 square miles was prepared on aerial photographs. Prospect pits and mine areas were sampled in detail. Approximately 80 water samples were collected along the flanks of Green Mountain and Crooks Mountain.

Uranium occurs both in the arkosic sandstones of the Wasatch (?) formation of Eocene age and in rocks of Cambrian age (fig. 29). To date no ore-grade deposits have been discovered in the Cambrian rocks.

At Crooks Gap, the Wasatch (?) formation is composed primarily of iron stained, coarse arkose containing thin lenses of carbonaceous, sandy shale and mudstone. Giant-boulder conglomerates are interbedded with the sandstones. The Cambrian rocks consist of thin, glauconitic, ferruginous limestone interbedded with ferruginous silty shales. The Cambrian rocks are disturbed by overthrusting.

The uranium deposits in the Wasatch (?) formation occur in the lower part of the formation and are associated with fine-grained carbonaceous beds or lenses, and with red and brownish-yellow iron stained sandstone. Uranophane appears to be the principal uranium mineral, but phosphuranylite has also been reported. Some ore in the Sno-ball claims occurs as flattened, irregular, concretionary masses generally less than 10 feet across.

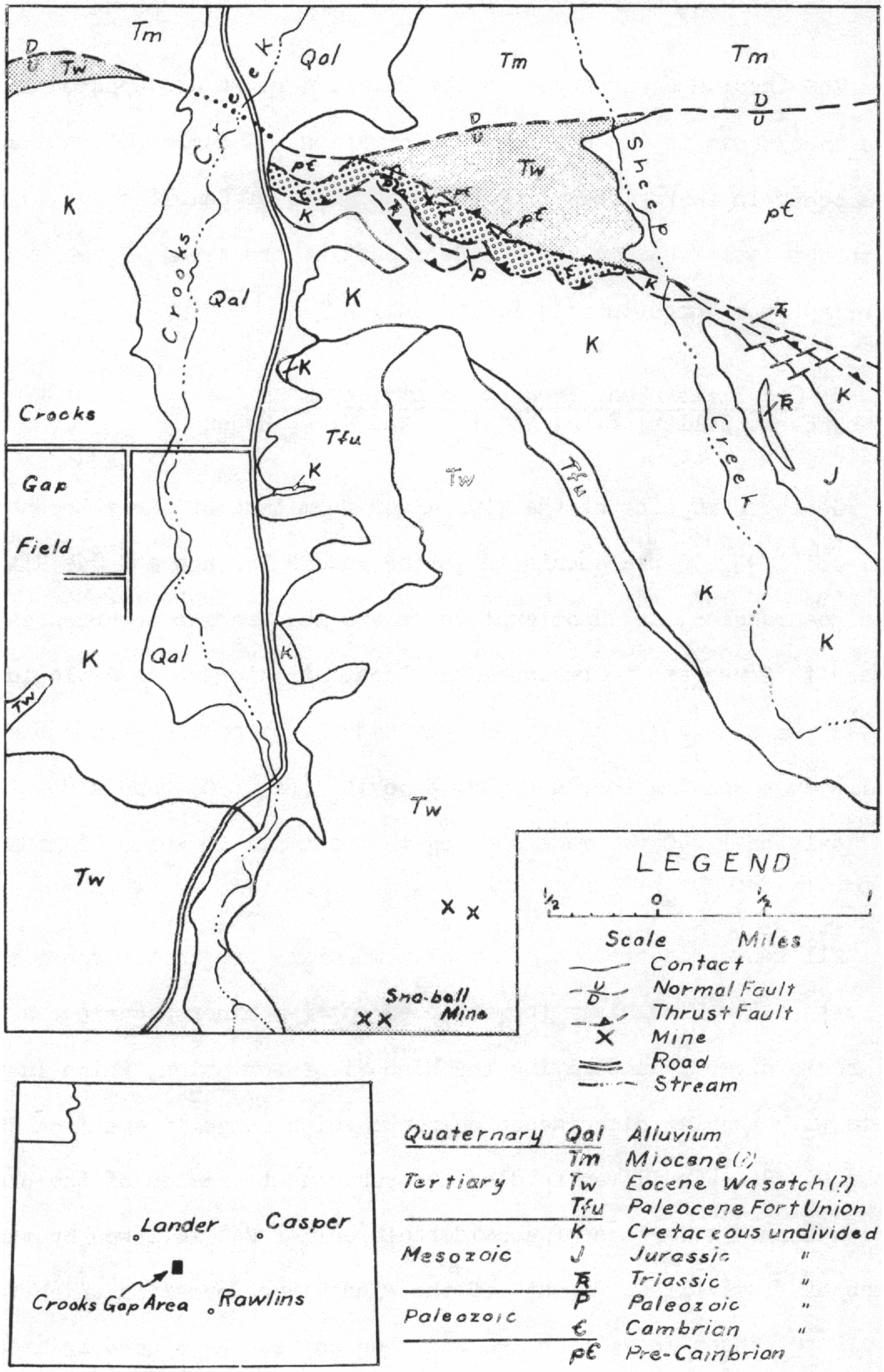


Fig. 29--Geologic Sketch Map of Part of the Crooks Gap Area, Fremont Co., Wyoming

The uranium occurrences in the Cambrian rocks are apparently less extensive than those in the Wasatch (?) formation. A number of radioactive anomalies occur in ferruginous limestone and shale of Cambrian age mainly along a thrust fault zone in the northern part of the area. Torbernite has been reported from gouge in this fault zone.

Gas Hills area, Fremont County, Wyoming
by H. D. Zeller, P. E. Soister, and H. J. Hyden

Geologic mapping of the Wind River formation of early Eocene age at a scale of 1:24,000 was completed in the Puddle Springs and Gas Hills $7\frac{1}{2}$-minute quadrangles, in an attempt to relate the uranium occurrences to sedimentary features and to regional and local structures. A geologic and topographic map at a scale of 1:6,000 was made by plane table of a one-square mile area showing the Lucky Mc. deposits (fig. 30), and a detailed map at a scale of 1:240 was made showing the main pit in which uraninite was found.

All known occurrences of uranium minerals are in the upper coarse-grained part of the Wind River formation except two minor occurrences in Mesozoic rocks directly underlying the Wind River formation, which in this area rests with angular discordance on rocks which range in age from Cambrian to Paleocene. Pre-Wind River folding and subsequent erosion of the older rocks which formed a surface of considerable relief was followed by the deposition of fluviatile sediments of the Wind River formation which first filled valleys eroded in soft shales and then buried the eroded or breached anticlinal structures.

No deposits in the post-Wind River rocks are known although radioactivity several times background has been detected in rocks of middle and

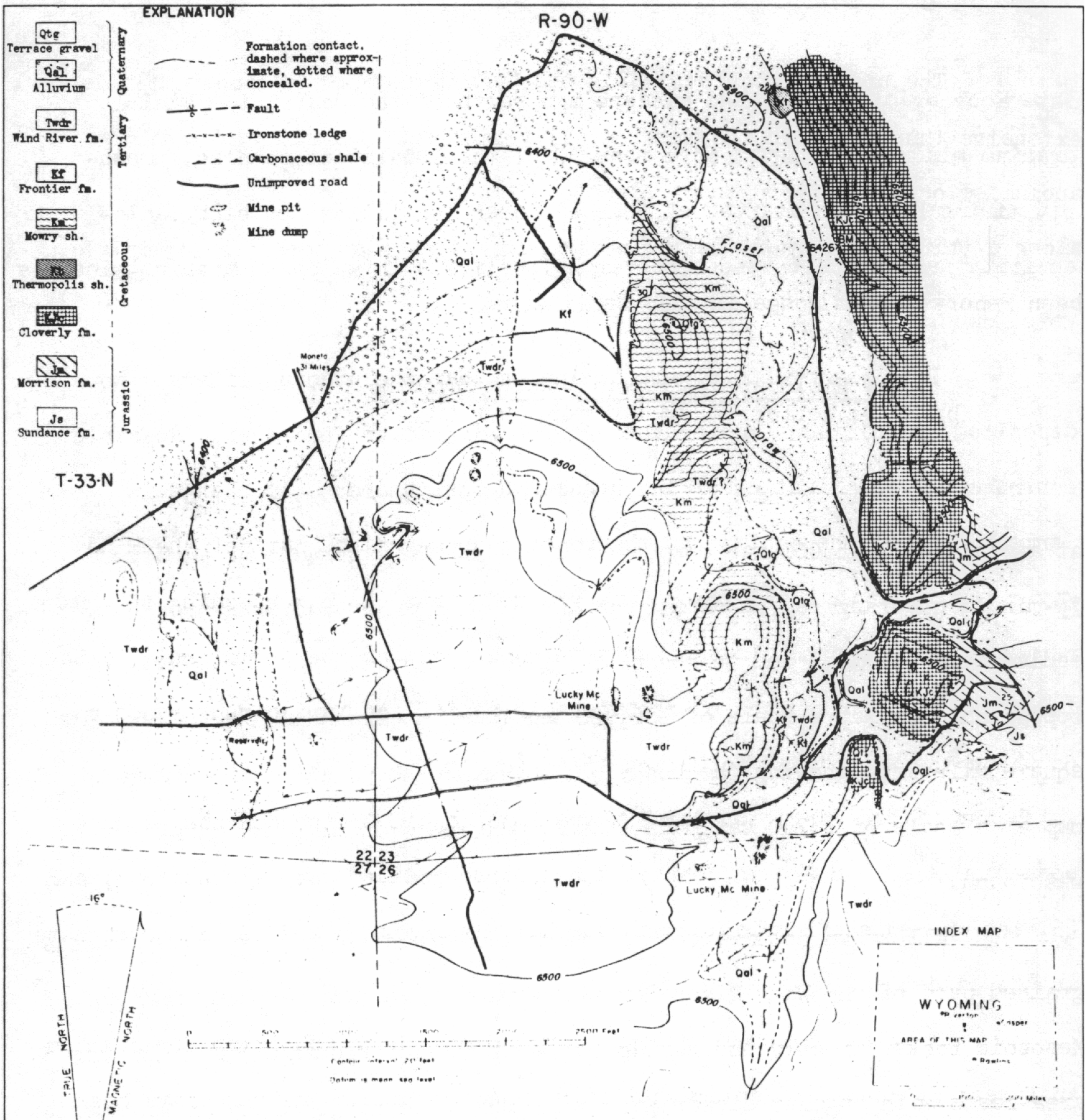


FIGURE 30 GEOLOGIC MAP SHOWING LUCKY MC. URANIUM DEPOSIT, FREMONT COUNTY, WYOMING

late Eocene, Oligocene, and Miocene age south of the district. Visible uranium minerals occur at more than 30 of the localities sampled. Open-pit mining has been started at four of these localities and high radioactivity has been detected at several localities in which no uranium minerals were found.

Preliminary field work indicates that the uranium minerals were deposited by solutions moving through the Wind River formation. Possible controls for localization of the uranium deposits are: (1) change in permeability at the contact of the upper coarse-grained part of the Wind River formation with the lower fine-grained part; (2) interbedding of permeable and impermeable sediments in upper part of the formation; (3) the irregular erosion surface of considerable relief and varied rock types upon which the Wind River formation lies; (4) faults of late Tertiary age which may afford "solution dams" where impermeable Cretaceous shales have been displaced and are in contact with coarse-grained porous sandstone; and (5) the presence of carbonaceous material, iron oxide, and calcium carbonate in the sandstone.

A total of 100 lithologic samples have been submitted for uranium analyses; of these, 56 semiquantitative spectrographic analyses have been requested. At least 15 samples will be submitted for thin-section study and mineralogical identification.

Seventy-six water samples were collected from springs, wells, and reservoirs in nine 7½-minute quadrangles and one area not covered by topographic maps. The water came from rocks ranging in age from pre-Cambrian to Quaternary. Ten of these samples were collected in the volcanic area of the Rattlesnake Range. A total of 45 samples has been analyzed to date.

The five highest uranium analyses are 310, 270, 120, 120, and 90 parts per billion. The first three of these are from springs in the Wind River formation in the mineralized district, and the last two are from wells in Quaternary alluvium in the valley of Muskrat Creek which drains a large part of the district. The water from the Cenozoic rocks is consistently higher in uranium than water from other rocks of the area.

Poison Basin area, Carbon and Sweetwater Counties, Wyoming
by G. E. Prichard and W. A. Chisholm

Geologic studies in the Poison Basin area near Baggs, southwestern Carbon County, Wyoming (figs. 31a and 31b) consisted of geologic mapping of about 275 square miles in Tps. 12 and 13 N., Rs. 90, 91, 92, 93, and 94 W. (fig. 32); detailed radiometric studies of uranium-bearing sandstone beds over an area of about 4 square miles; detailed sampling of sandstone bed outcrops and exposures in trenches and prospect pits, and drill holes; and the probing with a scintillation detector of 15 drill holes.

The Browns Park formation of Miocene age, which contains all the known uranium deposits in the Poinson Basin area, is about 300 feet thick and crops out over an area of about 12 square miles including Poison Basin, a topographic basin eroded largely from this formation. Higher than normal radioactivity is erratically distributed throughout the Browns Park formation, the highest radioactivity occurring in sandstone beds that crop out in SW$\frac{1}{4}$ sec. 4, S$\frac{1}{2}$ sec. 5, and SW$\frac{1}{4}$ sec. 32. No abnormal radioactivity was found in the underlying formations.

A radiometric grid survey of a group of low hills, known as Poison Buttes (fig. 33) shows the distribution of anomalous radioactivity on the ground surface. Abnormal radioactivity is erratically distributed both horizontally and vertically in outcropping sandstone beds.

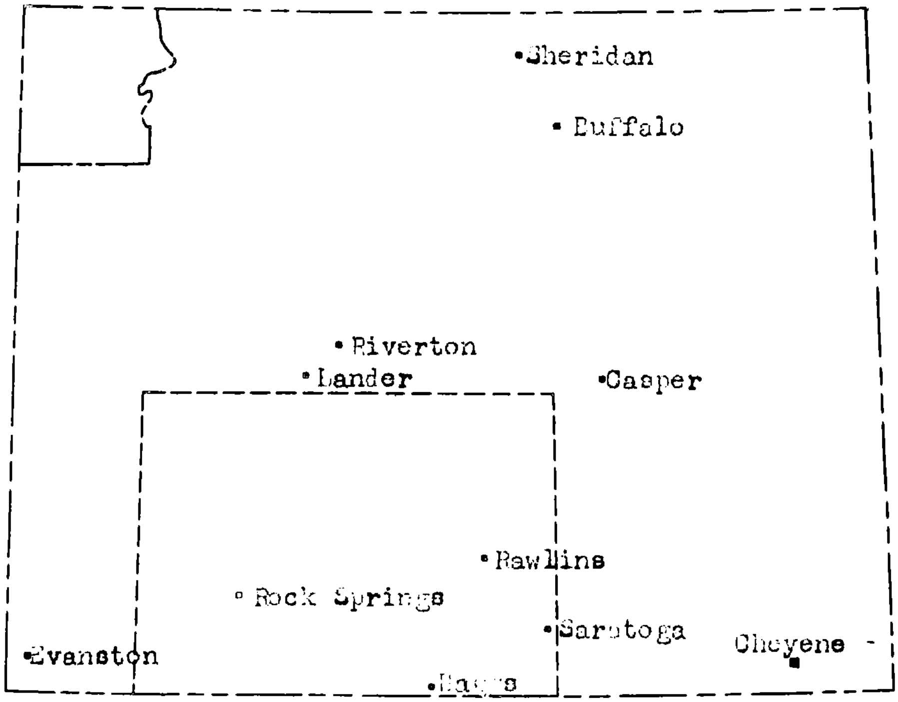


Figure 31a.- Index map of Wyoming showing location of inset map

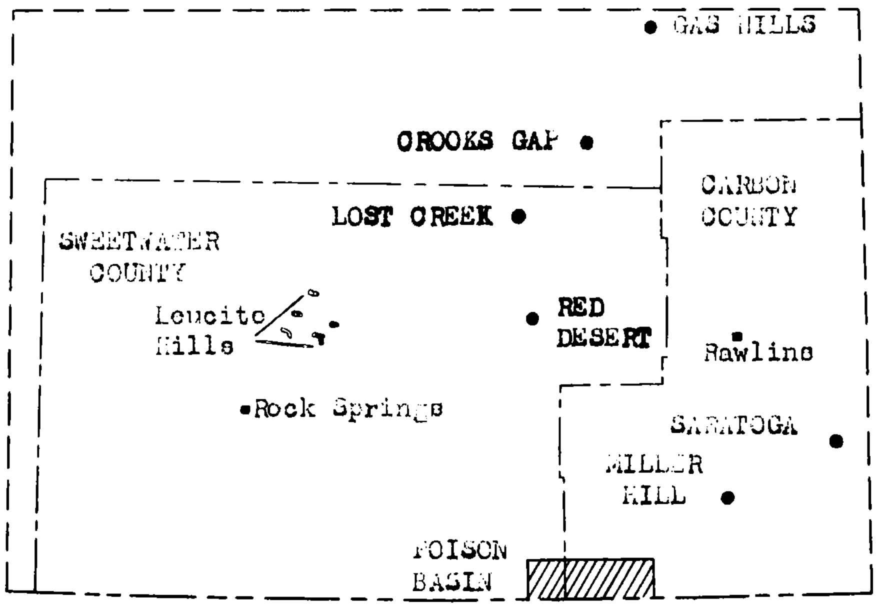
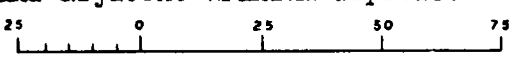


Figure 31b.- Inset map showing location of Poison Basin area and adjacent uranium deposits



● URANIUM DEPOSITS

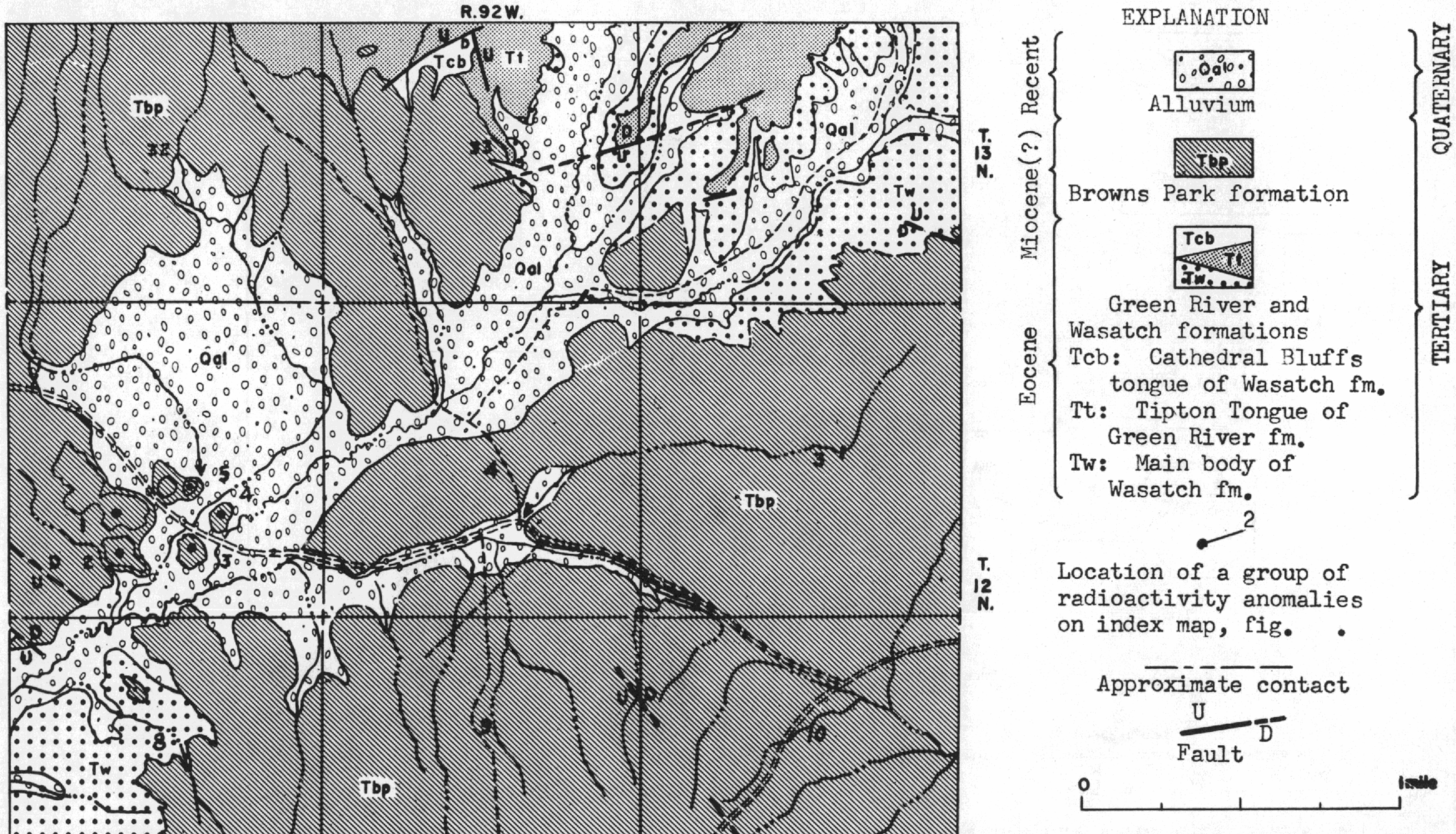


Figure 32.--Geologic map of part of Poison Basin area

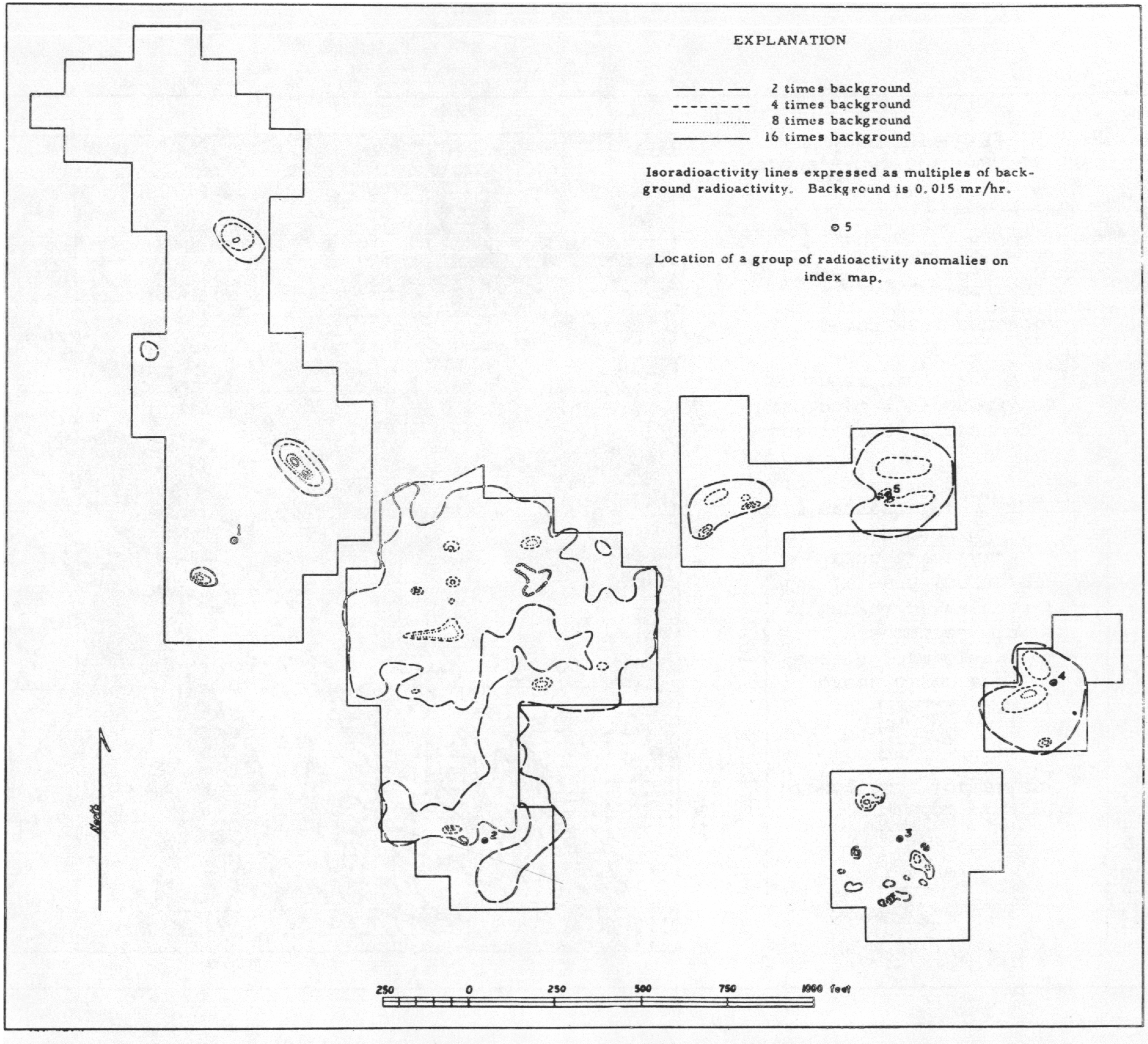


FIGURE 33.--RADIOACTIVITY SURVEY OF PART OF THE POISON BASIN AREA, CARBON AND SWEETWATER COUNTIES, WYOMING

Extensive exploration is being done in Poison Basin by mining companies and prospectors.

Datil Mountain area, New Mexico
by R. L. Griggs

The Mesaverde formation of Late Cretaceous age and the Baca and Datil formations of Tertiary age were mapped on a scale of 1:31,680 in an area of 168 square miles in the upper Alamosa Creek Valley along the northern edge of the Datil Mountains, Catron County, New Mexico. The mapped area includes all of Ts. 1 and 2 N., Rs. 10 and 11 W., and the two southern tiers of sections in T. 3 N., Rs. 10 and 11 W. The mapping was done to estimate the potentialities of the area for producing uranium and to learn the geologic controls of the concentration of uranium. Several prospects expose uranium-bearing rocks and a few sample loads of ore have been shipped. Uranium occurs in the upper part of the Mesaverde formation and in the Baca formation. Detailed studies indicate that the deposition of the uranium was influenced by ground water and that concentration of the uranium was controlled by variations in permeability and by minor structural features. Uranium is concentrated at the contact of porous sandstones with underlying impermeable shale beds and shale stringers. Minor synclines in the Mesaverde formation may have controlled the concentration of uranium at two localities. At one locality concentration of uranium is in the wedge-edge of a lenticular sandstone in the Baca formation. Yellow minerals (probably carnotite or tyuyamunite) are visible in some prospects but the uranium is associated mainly, in unidentified form, with ferruginous and carbonaceous material in sandstone.

In T. 2 N., Rgs. 9, 10, 11, and 12 W., uranium occurs in the uppermost member of the Mesaverde formation and in the basal part of the Baca formation. The estimated eU contents of seven grab samples are as follows:

Location	Estimated eU
Sec. 31, T. 2 N., R. 9 W.	0.003 percent
Sec. 35, T. 2 N., R. 10 W.	0.05 percent
Sec. 35, T. 2 N., R. 10 W.	0.05 percent
Sec. 19, T. 2 N., R. 10 W.	0.02 percent
Sec. 11, T. 2 N., R. 11 W.	0.05 percent
Sec. 11, T. 2 N., R. 11 W.	0.05 percent
Sec. 12, T. 2 N., R. 12 W.	0.05 percent

Uranium has been found at scattered points for a distance of about 60 miles along an east-west belt in western Socorro and eastern Catron Counties. These occurrences are in the Mesaverde and Baca formations a short distance north of where these units are overlain by acidic tuff which composes the Datil formation. In T. 1 N., Rgs. 5 and 6 W., uranium occurs with carbonaceous material in white to light gray sandstone beds in the Baca formation. The estimated eU contents of five grab samples are as follows:

Location	Estimated eU
Sec. 18, T. 1 N., R. 5 W.	0.2 percent
Sec. 18, T. 1 N., R. 5 W.	0.005 percent
Sec. 13, T. 1 N., R. 6 W.	0.5 percent
Sec. 24, T. 1 N., R. 6 W.	0.1 percent
Sec. 35, T. 1 N., R. 6 W.	0.1 percent

In sec. 22, T. 3 N., R. 16 W., a sample collected from a sandy shale in the Mesaverde formation is estimated to contain 0.03 percent eU.

URANIUM IN LIMESTONE

Saratoga area, Carbon County, Wyoming
by J. G. Stephens

The Saratoga area is in south-central Carbon County, Wyo. in the Saratoga valley, a topographic depression between the Medicine Bow Range and the Sierra Madre. Tuffaceous rocks of the Browns Park formation of Miocene age and the North Park formation of Pliocene age are exposed. Uranium occurs in the cherty limestone beds of the Browns Park formation, in pediment gravels of uncertain age, and in tuffaceous sediments of the North Park formation underlying these pediment gravels.

The uranium occurrence in the Browns Park formation is exemplified by a cuesta located five miles due west of Saratoga where the following section was measured.

Table 7.--Section of Browns Park silicified limestone 5 miles west of Saratoga, Wyoming.

Thickness, feet	Rock type	eU, percent
Top.		
1.3	Chert, very dark brown, limy	0.013
0.6	Thin limestone and dark chert	.008
1.6	Siltstone, very light greenish-gray	.003
2.8	Siltstone, buff, sandy	.003

Browns Park sediments dipping eastward approximately 10° are capped by a resistant chert bed. The dark chert is moderately radioactive whereas the underlying siltstone is only slightly radioactive. No visible mineralization was observed.

Both the gravel cover and the underlying North Park formation on a pediment remnant 5 miles south of Saratoga contain uranium minerals tentatively identified as vanadates (probably carnotite or tyuyamunite), occurring as a film in joints and around grains. No deposits of commercial interest were found.

King Mountain area, Texas
by D. H. Eargle

Uranium minerals were found in the Edwards limestone on a low bench of King Mountain about 2 miles ENE of McCamey, southwestern Upton County. The two occurrences are about a quarter of a mile apart; in a prospect pit about four feet square and ten feet deep near the southwestern edge of the bench, and in a pit in weathered limestone near the C. W. Brown No. 6 Della Bowen oil well. The minerals, identified as tyuyamunite and carnotite, form coatings along joint planes and cracks in the limestone, and partly fill tubular cavities in the weathered rock a few feet beneath the surface. The results of analyses of samples from these two localities are given in table 8.

Table 8.--Analyses of samples from King Mountain, Upton County, Texas

Serial No.	Type	Locality	Lithology	eU percent	U percent
210,152	Channel	Prospect pit,	Limestone	0.001	-----
210,153	"	3 to $5\frac{1}{2}$ ft.	"	0.002	-----
210,154	"	below surface	"	0.004	0.002
210,155	"		"	0.001	-----
210,156	Grab	Slush pit	"	0.003	-----
213,012	Selected	" "	Weathered ls. and carnotite	3.7*	8.52

* Estimate only; sample too small for routine analysis.

Although the deposit at this site is not large, radiometric traverses in the vicinity indicate that a considerable area is underlain by rocks as radioactive as those in which uranium minerals have been found. The uranium may have been leached from the Ogalalla formation of Tertiary age which probably once covered the bench. It is possible, however, that it was leached from the Kiamichi shale which shows unusual radioactivity and which overlies the Edwards limestone about 40 feet stratigraphically above the deposits.

Hueco Mountains area, Texas
by D. H. Eargle

Uranium minerals were found at scattered localities in the Hueco Mountains along the line between El Paso and Hudspeth Counties, west Texas. The uranium was first found in a cut on U. S. highway 62 in Hueco Gap. The minerals have been identified as carnotite and small amounts of tyuyamunite, coating boulders in the calichified surficial material, and to a less extent coating joint planes and cracks in the bedrock, the Hueco limestone of Permian age. The carnotite and tyuyamunite are associated with dendrites of manganese oxide. The limestone bedrock surface, beneath the surficial materials, shows considerable leaching and sink hole development prior to its covering by colluvium. The surficial material is assumed to be of Pleistocene age.

Carnotite, associated with mammillary deposits of secondary calcite, was found on the eastern flanks of Sabina Mountain, a mile-long ridge--an outlier of the Hueco Mountains in the Hueco bolson--2 to 3 miles south of U. S. highway 62, and about 5 miles west of the foot of the main range. The carnotite coats limestone pebbles and fills cracks in caliche beneath a landslide block of Hueco limestone. On the west flank of Sabina Mountain, at a slightly lower altitude than the locality on the

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east side of the mountain, carnotite coats not only the boulders in a thin deposit of calichified talus, but also surfaces of the bedrock along cracks and joint planes in the Hueco limestone. It was found in numerous pits over an area about 500 feet long and as much as 10 feet below the surface. Showings have also been reported from other pits along the same mountain. At another locality 2 miles north of highway 62 and about 4 miles north of Sabina Mountain in a saddle in another outlier of the Hueco Mountains, traces of carnotite appear in the soil about two feet below the surface and in cracks and joints in the Hueco limestone.

The numerous scattered localities where the carnotite minerals have been found suggest that uranium minerals may be widely distributed in the area. As the uranium minerals show low radioactivity they are apparently of recent geologic age. Additional field investigations in and near the Hueco Mountains, followed by collection and analysis of samples, will be undertaken.

URANIUM IN VEINS, IGNEOUS ROCKS, AND RELATED DEPOSITS

District studies

Colorado Front Range
by P. K. Sims

Field investigation of the Central City-Georgetown area, except for continuing studies in active mines, has been completed (fig. 34). Approximately 50 square miles (scale 1:6,000) and about 200,000 linear feet (scales 1:120 to 1:1,200) of underground workings were mapped during the past three years, and all mine dumps and accessible mines were examined for radioactivity.

The studies indicate that (1) although uranium is widespread in this part of the Front Range, known individual deposits are small, (2) a few mines probably will produce several hundred tons each, and (3) pre-Cambrian pegmatites, previously not recognized as possible sources of uranium, are potential sources of low-grade ore.

A summary of the uranium occurrences, including distribution, mineralogy, structural environment, and origin, was given in TEI-440; accordingly only new data are given here.

Tertiary vein deposits

At least ten mines now are being explored for uranium, and production is being made from the Carroll and Cherokee mines. During this report period a significant discovery of uranium was made on the Black Hawk Lode No. 2, the Tippecanoe, and Silent Friend claims (sec. 7, T. 3 S., R. 72 W.) on Silver Hill, in the northeast part of the Central City

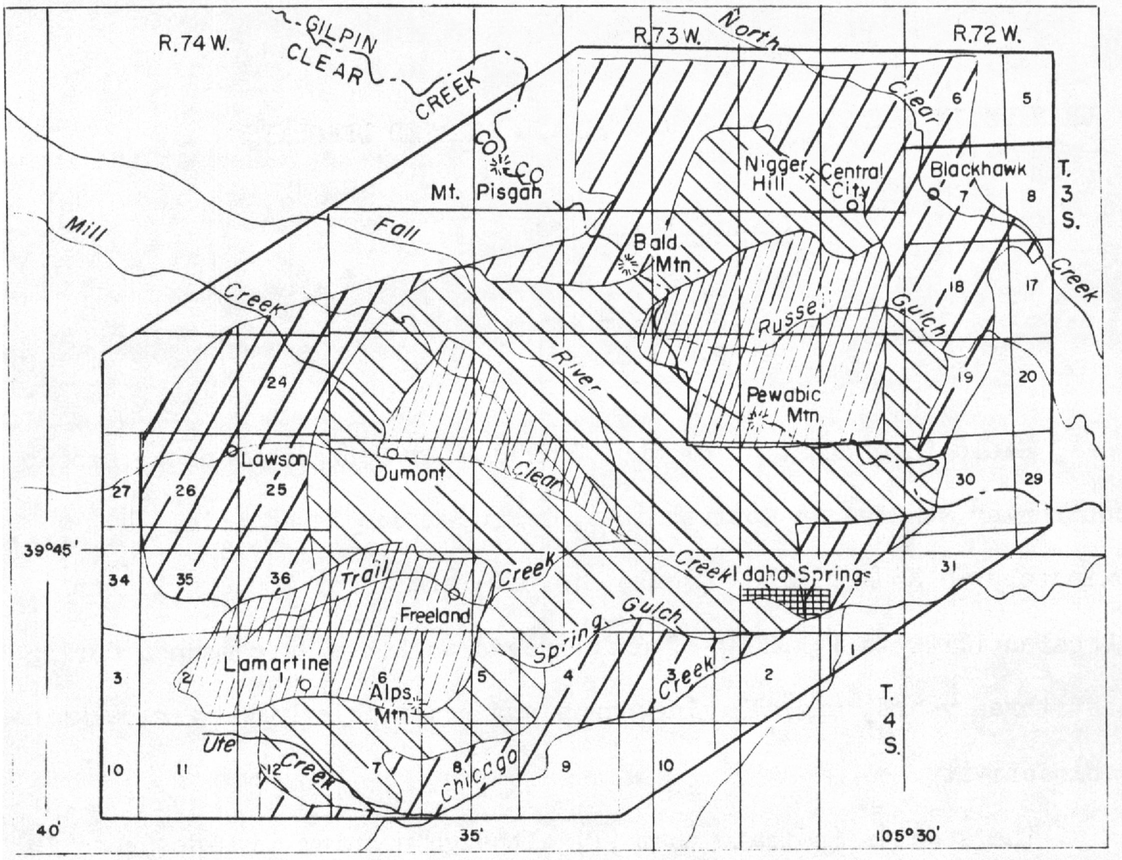
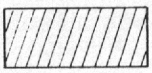


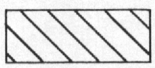
FIGURE 34

MAP SHOWING OUTLINE OF THE GEORGETOWN – CENTRAL CITY AREA, COLORADO FRONT RANGE PROJECT.

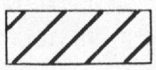
Explanation



Mapped July – November, 1952.



Mapped June – October, 1953.



Mapped June – November, 1954.

district, in an area not known previously to contain uranium. Two veins are known to be radioactive along a linear distance of 800 feet; the maximum radioactivity recorded is 3 mr/hr. The showings are in numerous shallow pits and a small adit. The uranium is in colored secondary minerals, which in part replace altered schist wall rocks, similar to known occurrences on Nigger Hill. The grade of the deposits is estimated to be between 0.1 and 0.2 percent U.

South of Clear Creek, in Clear Creek County, the operators of the Sunnyside tunnel (Wells and Harrison, 1954, USGS Circ. 345, p. 5) have found a pitchblende-bearing vein of possible commercial importance; small quantities of uranium were found in the mine by the USGS in 1951.

The uranium within Tertiary veins in the map area is nearly as widespread as other metals, but not so abundant. Some of the more promising veins, as for example those on Nigger Hill, are far outside the transition zone of hypogene mineralization as outlined by Leonard (1952) and King et al. (USGS Circ. 215, 1953, p. 6). Field studies largely substantiate the conclusion (Phair, TEI-247, 1952) that the uranium was derived from the widespread radioactive Tertiary bostonites.

Radioactive pre-Cambrian pegmatite

A type of pegmatite, abnormally radioactive over a wide area in Clear Creek and Gilpin Counties, appears promising locally as a substantial source of low-grade uranium ore. The uranium mineral is uraninite, and preliminary concentration tests on one property indicate that a good-grade concentrate can be produced by relatively inexpensive gravity-concentration methods.

A radioactive pegmatite on the Highlander claim in Virginia Canyon, about a mile north of Idaho Springs, is being mined from the Hudson tunnel by the Uncompahgre Uranium Corporation. The Survey made detailed studies of the claim during this report period. The pegmatite being mined at the Hudson tunnel is one of several radioactive pegmatites in this part of Virginia Canyon. The pegmatites individually are lenticular bodies from a foot or less to about 30 feet thick and a few tens to perhaps a hundred feet long. They crosscut the metasedimentary rocks they intrude. They consist predominantly of perthite, quartz, plagioclase, and biotite. Biotite is variable in quantity; at places it constitutes 10 percent or more of the rock and at other places it is sparse. For the most part it occurs in well-formed books, some of which are lath-shaped. Plagioclase probably is subordinate to perthite. The uraninite largely is associated with the biotite. At and near the surface uranophane and autunite are present. Other minerals include pyrite and molybdenite.

Geiger counter radioactivity measurements on the pegmatite gave an average of 0.2 mr/hr and a maximum of 0.5 mr/hr. Another pegmatite, 25 feet thick, gave similar readings. Preliminary data suggest that the pegmatites in the tunnel contain on the average slightly more than 0.1 percent uranium. A higher-grade product can be obtained by hand-sorting; some pegmatite containing one percent or more uranium is present.

Other bodies of the same type of pegmatite, equally as radioactive, are known. They include the pegmatite on the Waterloo dump in Russell Gulch, which Phair determined to be 1,200 to 1,400 million years old.

The radioactive pegmatite is thought to be related to the biotite-muscovite granite of the area, which also is more radioactive than the other granitic rocks and metasediments.

Ralston Buttes district, Colorado
by D. M. Sheridan and C. H. Maxwell

The Ralston Buttes district in the eastern foothills of the Colorado Front Range is becoming increasingly important as a potential source of uranium ore. To date, at least 20 occurrences of uranium minerals are known in the district (fig. 35); 12 of these are known to contain pitchblende. One of the properties containing high-grade pitchblende ore is in production. Four localities in the district are being explored.

Approximately 7 square miles were mapped (1:7,200) by the USGS in the area along Ralston Creek in the northern part of the district, and 1 square mile was mapped (1:20,000) in the Golden Gate Canyon area (fig. 35). Systematic traverses for radioactivity anomalies were made on 30 breccia reefs and branching fault structures, totalling about 50,000 feet in length.

All significant occurrences of pitchblende found to date are associated with base-metal sulfides in or near carbonate-bearing fault breccias of probable Tertiary age. In the Golden Gate Canyon area these occurrences seem to be localized in places where faults cut pre-Cambrian layers that are rich in hornblende or, more rarely, rich in biotite. According to Adams and Stugard (oral communication, 1954) this localization may be a chemical factor related to the iron in the minerals of the host rock. In the Ralston Creek area, several pitchblende occurrences are also associated with hornblende-bearing host rocks, and a layer rich in

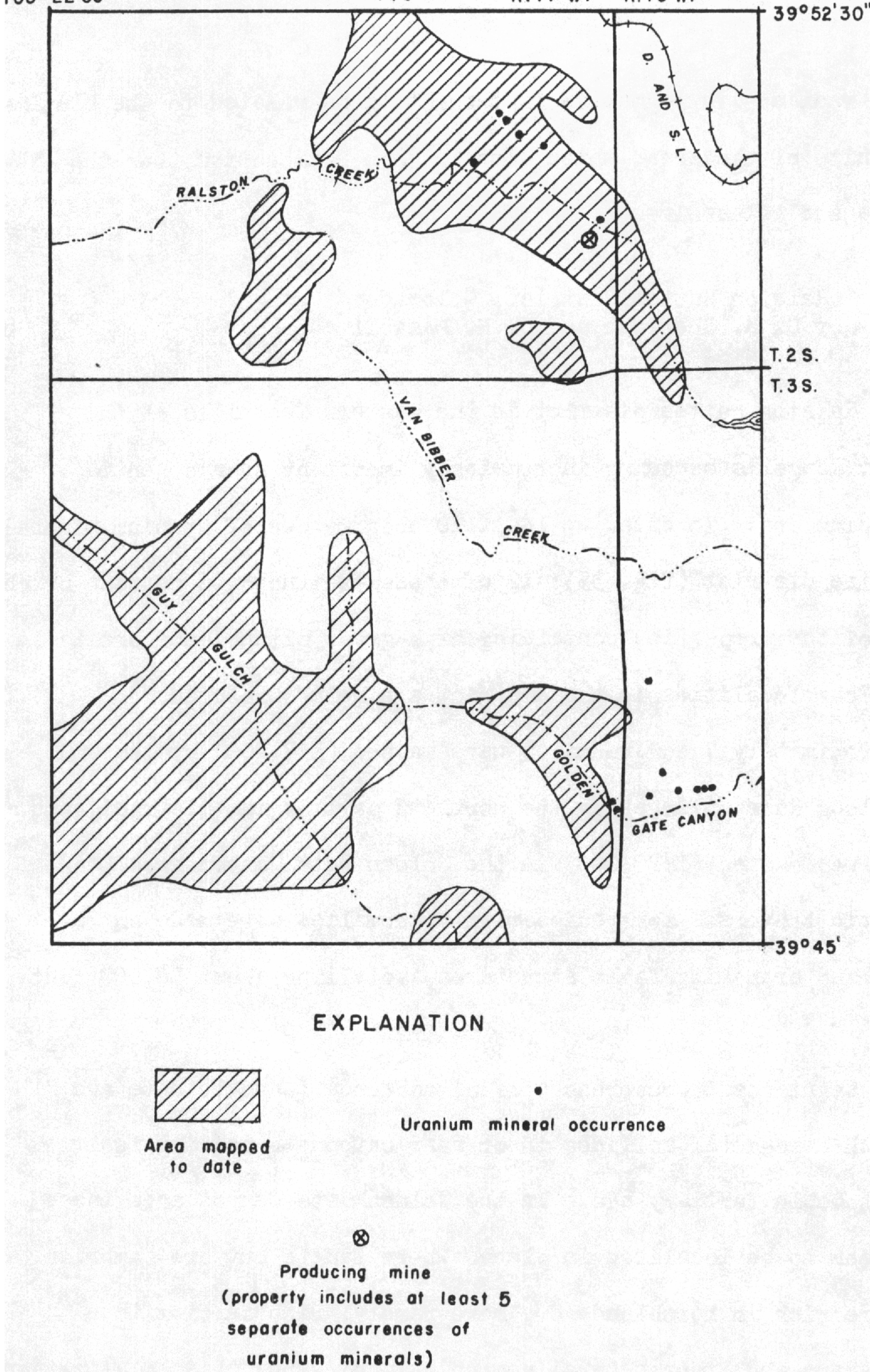


FIGURE 35 -- INDEX MAP OF THE RALSTON BUTTES QUADRANGLE, JEFFERSON COUNTY, COLORADO

0 1 2 3 4 5 Miles

lime-silicate minerals forms the footwall of one of the ore-bodies in the producing mine. Native bismuth is associated with copper sulfides in one of the pitchblende-bearing structures near Ralston Creek.

Of particular interest is the experience of various private exploration groups with radioactivity anomalies that registered only 2 to 3 times the background reading. At a surprising number of anomalies, excavation of 2 to 8 feet disclosed uraniferous material of potential interest. Other similar anomalies, however, disclosed only low-grade material at depth. In a few places radioactive anomalies were caused by monazite in pegmatites.

Boulder Batholith, Montana
by G. E. Becraft

Geologic mapping (scale 1:24,000) of three $7\frac{1}{2}$-minute quadrangles and part of a fourth was completed during the report period. Figure 36 shows the area mapped in detail to date. Most of the known radioactivity anomalies in the quadrangle are also shown.

Several radioactivity anomalies were detected in the Ten Mile Creek area adjacent to the Rimini area, where uranium minerals have previously been noted. These anomalies are associated with base-metal deposits in quartz monzonite.

Between the Little Boulder and Boulder Rivers, several anomalies associated with chalcedonic vein zones were found. Radioactive samples containing a secondary uranium mineral were found on the dump of a caved shaft northeast of the headwaters of the North Fork of the Little Boulder River. The mineral is in a vein consisting principally of quartz with abundant pyrite.

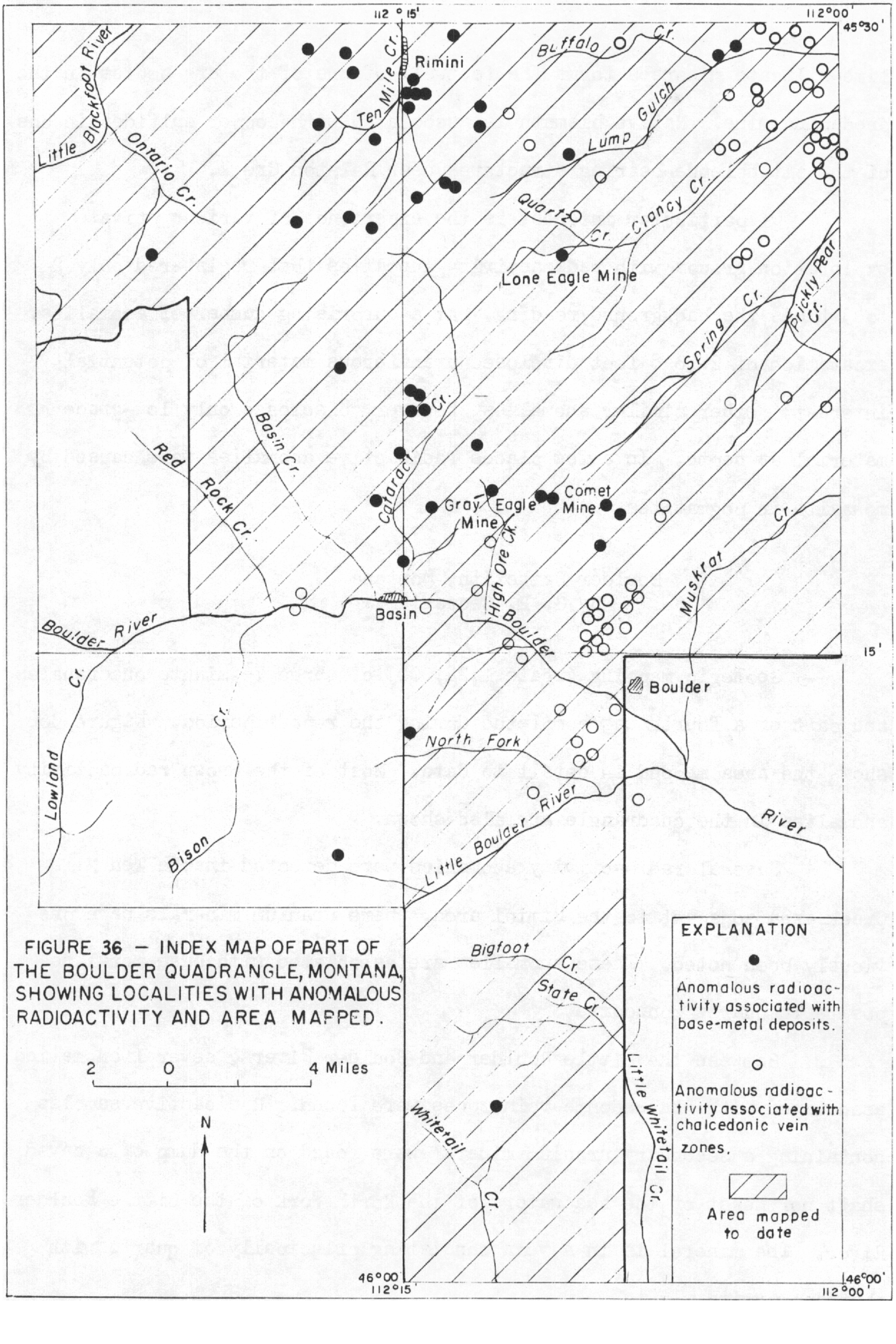


FIGURE 36 — INDEX MAP OF PART OF THE BOULDER QUADRANGLE, MONTANA, SHOWING LOCALITIES WITH ANOMALOUS RADIOACTIVITY AND AREA MAPPED.

An exploration program at the Red Rock mine about 2 miles west of Basin did not disclose uranium of ore grade. The exploration consists of two adits, one south and one north of the Boulder River. The vein ranges in width from about one foot to four feet and consists principally of light-gray to medium-gray chalcedony in altered Cretaceous volcanic rocks. Several samples across the vein indicate a range in grade from about 0.05 percent U to about 0.1 percent U, over an average width of about 2 feet. Analyses indicate a total rare-earth-oxides content of 0.10 to to 0.17 percent and a thorium content of less than 0.002 percent.

The geology and radioactivity surveying were completed in the northwest part of the Clancy quadrangle. All known anomalies are shown on figure 37. In the vicinity of the White Pine mine, several anomalies were detected. The highest radioactivity is in an adit about 250 feet north of the White Pine. About 75 feet from the portal a reading of 0.65 mr/hr was obtained with a background of 0.001 mr/hr. The radioactivity was restricted to a fault zone containing quartz and galena.

Three radioactivity surveys were made across the sedimentary section exposed in the Radersburg quadrangle, which include formations ranging in age from pre-Cambrian through Cretaceous. Several shales in the section have a relatively high background count and were sampled, but the uranium content is estimated to be low.

Thomas Range, Utah
by M. H. Staatz

The objective of the Thomas Range project is a detailed study of the relationship of the uranium deposits with the fluorine-rich rhyolites,

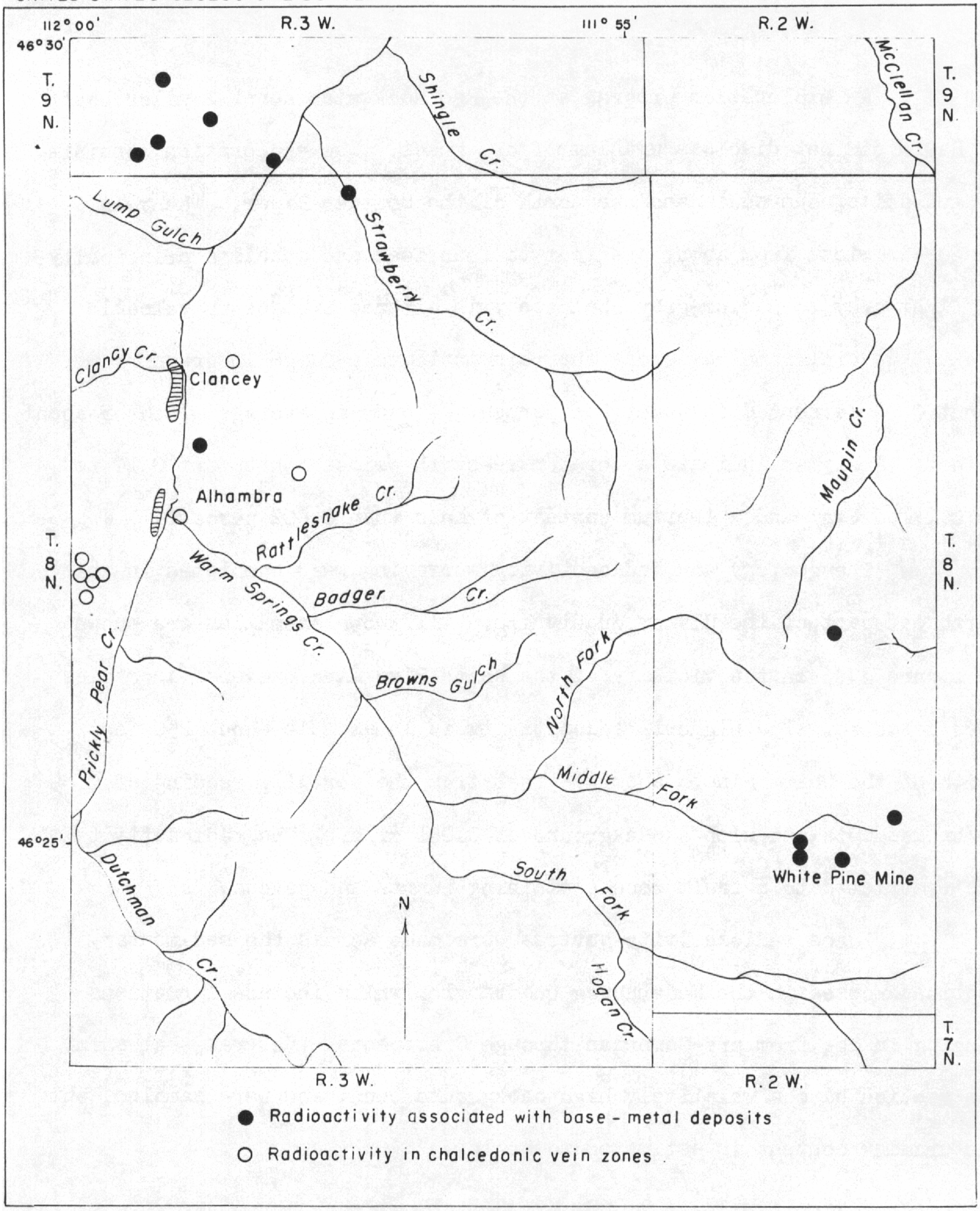
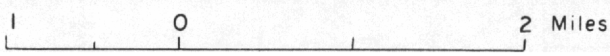


FIGURE 37--MAP OF NORTHWEST CORNER OF CLANCY QUADRANGLE, MONTANA, SHOWING AREAS OF ANOMALOUS RADIOACTIVITY.



and to search for new uraniferous fluorspar bodies. Detailed stratigraphic sections of sedimentary and volcanic rocks will be made to allow determination of the major mappable units. The entire area, comprising one and one-third 15-minute quadrangles, will then be mapped geologically on a scale of 1:40,000. The mapping will be accompanied by petrographic examination of the volcanic rocks and detailed study of all ore deposits.

Field work, begun in mid-October, consisted of reconnaissance examination of the area and measurement of several stratigraphic sections. Since the last report (Osterwald, 1952, TEM-534) on the uraniferous fluorspar deposits in the western part of the Thomas Range, four new deposits have been discovered. Survey personnel sampled these deposits as well as the deeper workings of the Bell Hill mine. The lower two levels of this mine also were mapped.

Jarbidge, Nevada
by R. R. Coats

Field work on this project was begun in July and suspended the middle of September. About 70 square miles were mapped on a scale of 1:48,000. Field studies were made of the distribution of radioactivity in the younger sequence of rhyolitic welded tuffs; no significant variations have yet been found. Mapping has indicated a more complicated structural history than was previously known. The pre-Cretaceous sedimentary rocks have been subdivided into four units, none of which has yet been dated, or has furnished paleontologic evidence on which dating might be based. Recent prospecting by individuals has disclosed tungsten deposits along the contact between the granitic rocks and the Paleozoic (?) limestone along the western edge of the quadrangle.

General geologic studies

Occurrence of uranium in veins and igneous rocks
by George Phair and John Antweiler

Field work on the Front Range porphyries and their bearing on pitchblende deposition was completed. Analytical work on the same rocks was essentially finished with the exception of additional thorium determinations which are now in progress.

As one of the chief difficulties in the way of attempts to trace the path of the radio-elements during differentiation has been the lack of adequate methods of thorium analysis in the very low range, operative study of available methods of thorium determination was initiated. Samples of porphyry containing thorium in the range from 100 to 500 ppm according to previous chemical determinations, both colorimetric and nephelometric, are used as a basis of comparison. These samples will be reanalyzed chemically, radiochemically and by X-ray fluorescence. Finally, splits of the same samples will be sent to P. Hurley at the Massachusetts Institute of Technology to be used as standards for calibrating the method of thorium determination by gamma-ray spectrometry. The pooled results should not only represent the best thorium data yet obtained on igneous rocks, but should provide controlled tests of the precision and accuracy of the various techniques, most of which are still in the development stage.

Zonal relations of uranium deposits in metalliferous districts
by S. R. Wallace and D. C. Laub

Six weeks were spent in the Gold Hill district, Boulder County, Colo., continuing the study made by R. H. Campbell and Max Schafer in 1953.

The work consisted of checking additional localities for radioactivity and of mapping and sampling selected mine workings.

The economic metal deposits of the Gold Hill district are fissure veins. Gold telluride veins are distributed throughout the mineralized parts of the district and apparently bear no direct genetic relation to the relatively few pyritic gold veins or to the lead-zinc-silver veins which Goddard (Colo. Sci. Soc. Proc., v. 14, no. 4, 1940) believes may be both earlier and later than the telluride veins.

The data now available indicate that parts of many veins of all types are anomalously radioactive. Anomalous radioactivity was found also along small iron-stained fractures in fresh country rock far removed from any known veins. It is concluded that the present distribution of radioactivity may be the result of precipitation of uranium compounds from: (1) hydrothermal solutions in which the uranium was a primary constituent of the solutions; (2) hydrothermal solutions in which the uranium was extracted from uraniferous bostonite, pegmatite, or Silver Plume granite, during migration, and; (3) meteoric water that has leached and transported uranium from any of the pre-existing uranium-bearing vein or rock types.

It now appears that district zoning cannot be demonstrated within the Gold Hill district and that widespread--though generally low-intensity--anomalous radioactivity shows no definite correlation with vein type. No economic concentrations of uranium are believed to exist in the district.

In addition to the work at Gold Hill, six weeks were spent in the Bisbee district, Arizona, to study the relation of uranium to zoning around deposits of the porphyry-copper type. Various types of mineralized ground, both on the surface and in the mines, were sampled and examined for radioactivity. Samples of mine water and various mill and smelter products also were collected.

Low-grade disseminated copper ore in the Sacramento Hill stock, Bisbee district, exhibits no anomalous radioactivity, nor do the concentrates of this ore. Abnormal radioactivity is associated with relatively high-grade replacement ore bodies in Paleozoic limestones that partially surround the Sacramento Hill stock. The replacement ore bodies may be divided into two general types: (1) chalcopyrite-bornite-pyrite ore with generally lesser amounts of zinc and lead sulfides, and (2) galena-sphalerite ore containing essentially no copper. In a few places ore of both types is found in the same ore body.

Results of radioactivity traverses in the mine workings suggest that the copper ore is generally more radioactive than the lead-zinc ore, but there are several apparent exceptions.

URANIUM IN CARBONACEOUS ROCKS

Coal and lignite

Northwestern South Dakota, southwestern North Dakota, and eastern Montana
by J. R. Gill

Twelve occurrences of uranium-bearing lignite, carbonaceous shale, or sandstone estimated to contain 0.10 percent U or more were discovered in six widely separated areas. Two occurrences are in Montana, seven in South Dakota, and three in North Dakota. Locations are shown on figure 38, which also indicates areas that, on the basis of lithology and spot checks for radioactivity, appear to be favorable for the discovery of additional occurrences of uranium. These occurrences are summarized below.

Northwestern South Dakota, Harding County

North Cave Hills, Riley Pass deposit (fig. 39).--Discovery by the USGS of uranium minerals in sandstone in the Slim Buttes and subsequent radioactivity surveys by the AEC led to the discovery by prospectors of strippable deposits of lignite containing meta-autunite in the North Cave Hills. The deposits occur in the Tongue River member of the Fort Union formation of Paleocene age.

Reconnaissance mapping and preliminary analytic data indicate that an area of approximately 460 acres is underlain by lignite averaging 1.4 feet in thickness and containing about 0.20 percent U. In addition, 1,050 acres adjacent to this deposit may contain lignite of comparable grade.

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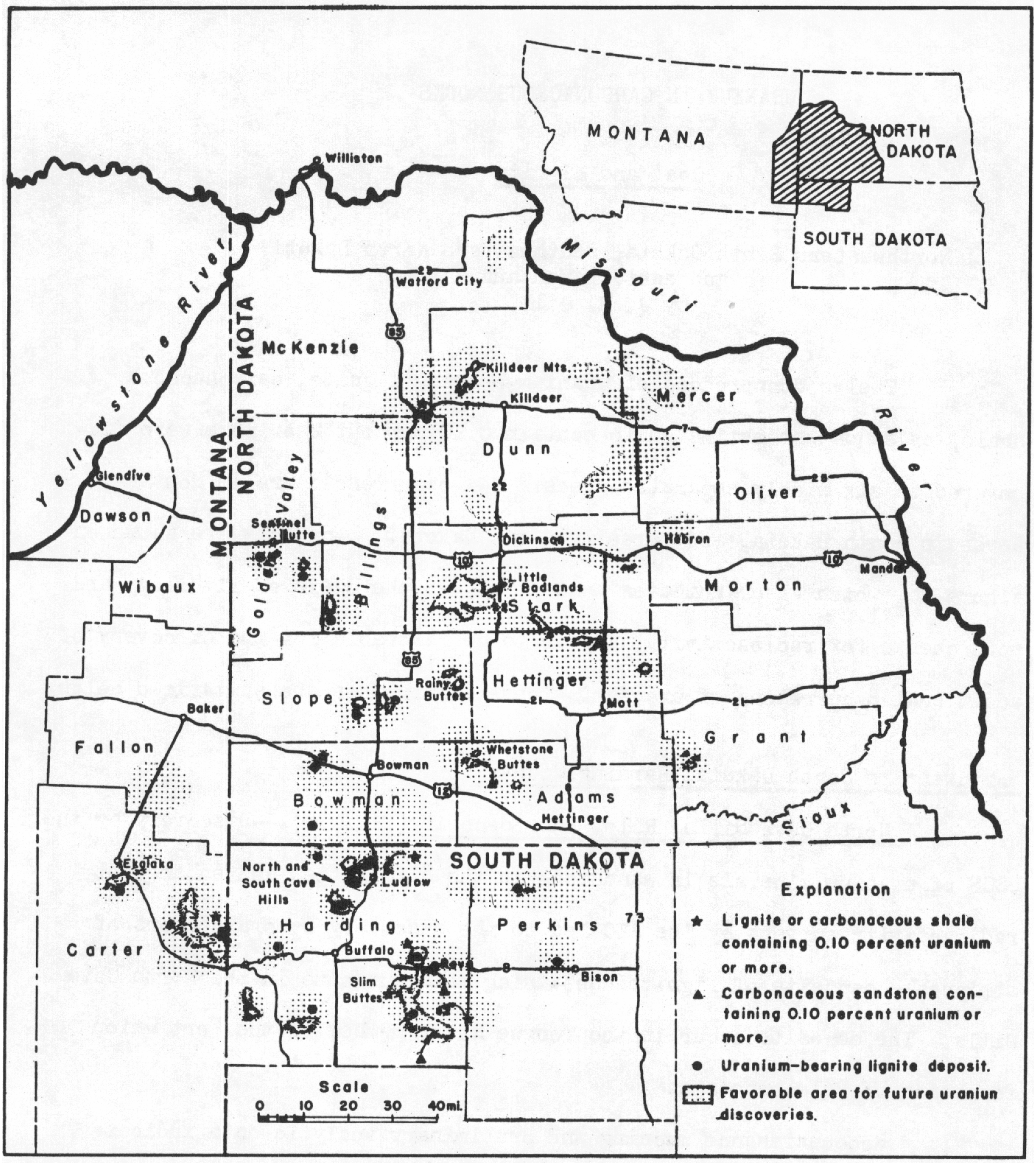

FIGURE 38-- RECENT URANIUM DISCOVERIES IN MONTANA, NORTH AND SOUTH DAKOTA AND FAVORABLE AREAS FOR FUTURE DISCOVERIES.

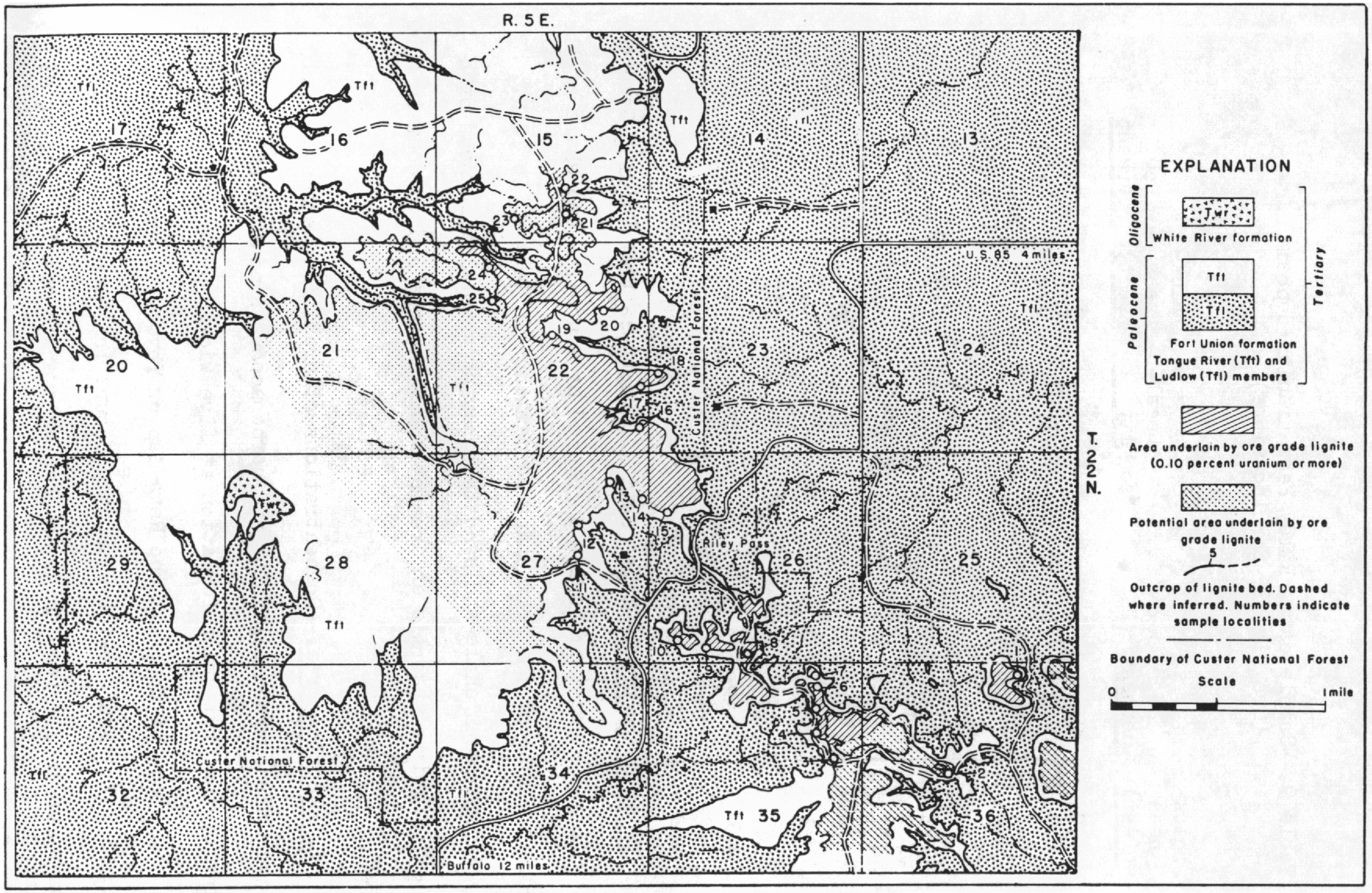

FIGURE 39--GEOLOGIC MAP OF RILEY PASS AUTUNITE-BEARING LIGNITE DEPOSIT, NORTH CAVE HILLS, HARDING COUNTY, SOUTH DAKOTA

Table 9.--Sample data, Riley Pass uranium deposit
(See fig. 39 for locations)

Locality	Thickness (feet)	eU, percent
1	1.0	0.66
2	0.8	.002
3	0.8	.002
4	0.9	.10
5	1.0	.27
6	1.3	.30
7	1.3	.31
8	1.1	.10
9	0.9	.10
10	0.9	.22
11	1.5	.13
12	1.2	.05
13	1.3	.15
14	1.7	0.27
15	1.3	.14
16	2.0	.64
17	2.0	.15
18	2.0	.10
19	0.8	.21
20	2.0	.03
21	0.8	.02
22	0.8	.02
23	1.1	.01
24	1.5	.03
25	1.0	.008

Tepee Butte area.--Tepee Butte in north-central Harding County about 12 miles northeast of Ludlow is capped by sandstone and shale of the Tongue River member of the Fort Union formation. In sec. 7, T. 22 N., R. 7 E., carbonaceous shale and sandstone having a total thickness of 4 feet is estimated to underlie an area of about 4 acres and to contain 0.40 percent eU.

Slim Buttes area.--Concentrations of uranium in excess of 0.10 percent were discovered in lignite and carbonaceous sandstone of the Ludlow member of the Fort Union formation at five widely separated localities. The most important of these is the Reva Gap or Thybo occurrence (sec. 10, T. 18 N., R. 8 E.) where metatyuyamunite occurs in sandstone. The mineralized sandstone is 3.2 feet thick and has an average uranium content of 0.68 percent. A summary of occurrences in the Slim Buttes area is given in table 10.

Table 10.--Uranium occurrences in the Slim Buttes area

Location (sec., T., R.)	Type of deposit	Thickness (feet)	U content (percent)
10-18N-8E	Sandstone	3.2	0.68
32-17N-9E	Lignite	1.0	0.11
30-17N-9E	Lignite	1.7	0.16
20-18N-8E	Lignite	1.0	1.0 est.
19-19N-8E	Lignite	1.5	0.2 est.

In addition to the above localities, prospectors have found several small occurrences of carnotite in tuffaceous sandstone beds of the Chadron formation of Oligocene age in the south end of the Slim Buttes. These occurrences, which are similar to the Cedar Canyon deposit (TEI-411), are probably not of commercial importance.

West Short Pine Hills.--The West Short Pine Hills in southwestern Harding County are capped by beds of tuffaceous sandstone, siltstone, and limestone of the Arikaree formation of Miocene age. In sec. 24, T. 17 N., R. 1 E., anomalous radioactivity is associated with thin lenses of freshwater limestone and siltstone. These rocks have an areal extent of several hundred acres and are estimated to contain between 0.01 and 0.1 percent U.

Eastern Montana, Carter County

Long Pine Hills area.--The Long Pine Hills, located in southeastern Montana near the South Dakota state line, are formed by rocks of the Hell Creek formation of late Cretaceous age, the Ludlow member of the Fort Union formation of Paleocene age, the Chadron formation of Oligocene age, and the Arikaree formation of Miocene age. A summary of occurrences in this area is given in table 11.

Table 11.--Uranium occurrences in the Long Pine Hills area

Location (sec., T., R.)	Type of deposit	Formation	Thickness (feet)	U content (percent)
29-2S-61E	Sandstone*	Hell Creek	0.5	0.2 est.
20-2S-62E	Lignite	Fort Union	1.0	0.1 est.
34-2S-61E	Siliceous shale	Arikaree	3.0	0.01-0.1 est.

*At the Rock No. 1 claim sandstone contains a visible uranium mineral.

In addition to the above localities, anomalous radioactivity is associated with sandstone beds of the Ludlow member of the Fort Union formation exposed along the east side of the Long Pine Hills.

Southwestern North Dakota

Rhame area, Bowman County.--A 0.5-foot carbonaceous shale bed in the Tongue River member of the Fort Union formation, exposed in the road cut of U. S. highway 12, 1.5 miles east of Rhame (sec. 25, T. 132 N., R. 103 W.), is estimated to contain between 0.1 and 0.2 percent eU.

Whetstone Butte area, Adams County.--Sandstones and shales of the Tongue River member of the Fort Union formation of Paleocene age are disconformably overlain by coarse, cross-bedded sandstones of the White River formation of Oligocene age. A 2.9-foot uranium-bearing sandstone bed in the Tongue River member crops out 60 feet beneath the base of the White River formation. The upper 0.4 foot of this bed contains a pale yellow uranium mineral coating sand grains and is estimated to contain 0.2 percent eU. The lower 2.5 feet of this bed is less radioactive and is estimated to contain between 0.01 and 0.1 percent eU.

Killdeer Mountain area, Dunn and McKenzie Counties.--A 0.8 foot bed of lignitic shale exposed in the road cut of North Dakota highway 7 (sec. 14, T. 146 N., R. 99 W., McKenzie Co.) is estimated to contain 0.1 percent eU.

Other areas.--Anomalous radioactivity is associated with fresh-water limestone in the White River group of Oligocene age on Young Man, Antelope (Custer), Long, and Lefor Buttes in Stark County, Shepherd (Star) Butte in Hettinger County, and Sentinel Butte in Golden Valley County. Anomalous radioactivity is also associated with beds of sandstone and shale in the Golden Valley formation of Eocene age and in the Sentinel Butte shale and Tongue River members of the Fort Union formation near Bullion Butte in Billings County; Little Badlands in Stark County; Grassy Buttes in McKenzie County; and Buffalo Springs in Bowman County.

Eastern Red Desert area, Sweetwater County, Wyoming
by Harold Masursky

Field geologic studies in the eastern Red Desert area were completed during 1953. Mineralogic, size distribution, and permeability investigations have continued and generally substantiate previously reported conclusions. Experiments on the solubility of uranium in natural water and its adsorption on coal, in collaboration with Wayne Mountjoy, indicate the mobility of uranium and high reactivity of coal. Chemical and semi-quantitative spectrographic analyses showing that the organic shale at Eagle's Nest has a greater content of trace metals where it is intimately interbedded in contact with coarse, permeable sandstone suggest an epigenetic emplacement of uranium and trace metals (fig. 40). Spectrographic analyses of trace elements in granite and volcanic rocks present in adjacent areas are being used to determine the probable source of the uranium in the Red Desert deposits.

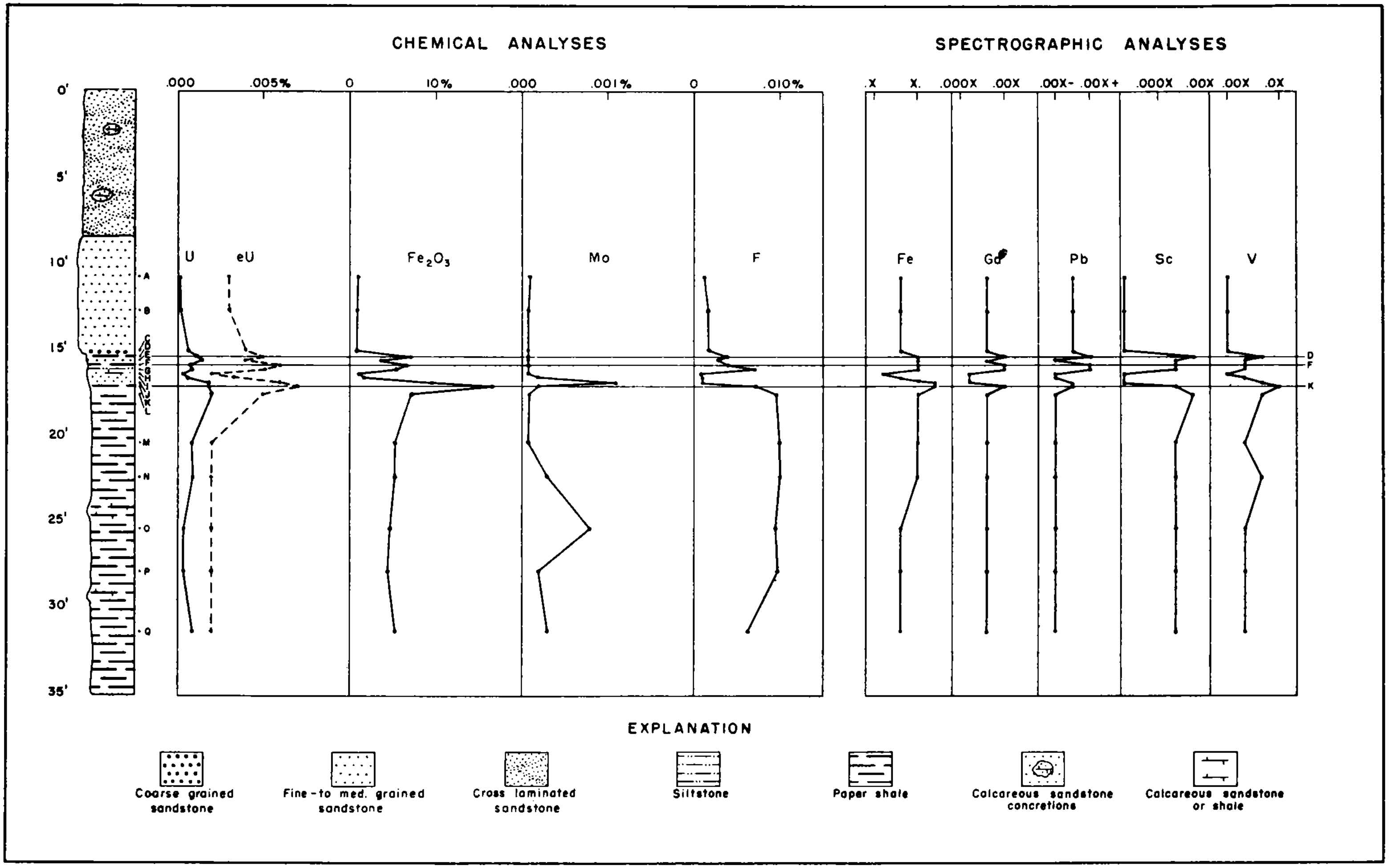

FIGURE 40.- DIAGRAM SHOWING DISTRIBUTION OF SELECTED ELEMENTS IN INTERBEDDED SANDSTONE AND PAPER SHALE IN THE WASATCH FORMATION EXPOSED AT EAGLE'S NEST ALONG LOST CREEK, RED DESERT AREA, WYOMING.

Black shale

Chadron area, Nebraska and South Dakota
by R. J. Dunham

About 250 square miles in northeastern Dawes County and northwestern Sheridan County, Nebraska, and southern Shannon County, South Dakota, was mapped on aerial photographs at scales of 1:20,000 and 1:31,680. Concentrations of 0.003 to 0.013 percent U occur in two kinds of deposits.

Uranium is concentrated sporadically in the Carlile, Niobrara, and Pierre formations of Cretaceous age in gray shales and marls immediately below the base of an altered zone formed by weathering of the Cretaceous strata. The maximum known uranium content in shale of the altered zone is 0.01 percent, and in most places the content is less than 0.003 percent U. Greatest uranium content is restricted generally to the highest part of the highest and thinnest remnant or pinnacle of unaltered shale.

A second type of uranium accumulation is found near the contact of the Chadron and Brule formations in the White River group, where weak radioactivity appears to be coextensive with the base of a non-marine gypsum sequence more than 200 feet thick and more than 10 miles long. Uranium is disseminated in parts of a 5- to 20-foot section of claystone, gypsum, and interbedded freshwater limestone at the base of the gypsum sequence. A sample of the limestone contains 0.012 percent U. Unevenly high radioactivity is measurable in almost all large exposures of the base of the gypsum sequence. Estimated uranium content averages 0.005 percent in about 5 feet of beds through a fourth of the outcrop investigated. In Sec. 3, T. 34 N., R. 47 W., in the northeastern part bedded gypsum and gypsiferous clay contain autunite and metatyuyamunite (?) which coat fracture surfaces. Channel samples of a 3-foot bed of laminated gypsum contain 0.13 percent U, and samples of a 2½-foot gypsiferous claystone bed average 0.25 percent U. These occurrences apparently are small.

About 20 feet in the middle part of the Sharon Springs member of the Pierre formation exhibits radioactivity of two to four times background throughout the area. Two samples from the richest part of the interval show 0.003 percent eU and 0.001 percent U, and 0.007 percent eU and 0.001 percent U. The Sharon Springs is a hard black marine shale that bears abundant fish remains and pyrite.

Western Kansas and eastern Colorado
by E. R. Landis

Outcrops of black shale in the lower part of the Pierre formation of Cretaceous age were examined and sampled in four general areas in western Kansas and eastern Colorado (see index map, fig. 41). These areas are in Wallace and Logan Counties, Kans.; Cheyenne and Kiowa Counties, Colo.; Crowley and Pueblo Counties, Colo.; and Las Animas County, Colo. Results of analyses and field observations indicate that the shale does not contain more than 0.008 percent U at any locality at which it was examined.

Tuffaceous and carbonaceous rocks were examined at many localities in western Kansas and southeastern Colorado. A sample of silicified limestone from the Ogallala formation in western Clark County, Kans., contains 0.01 percent U. A volcanic ash bed in the Ogallala formation in Ness County, Kans., contains 0.008 percent U.

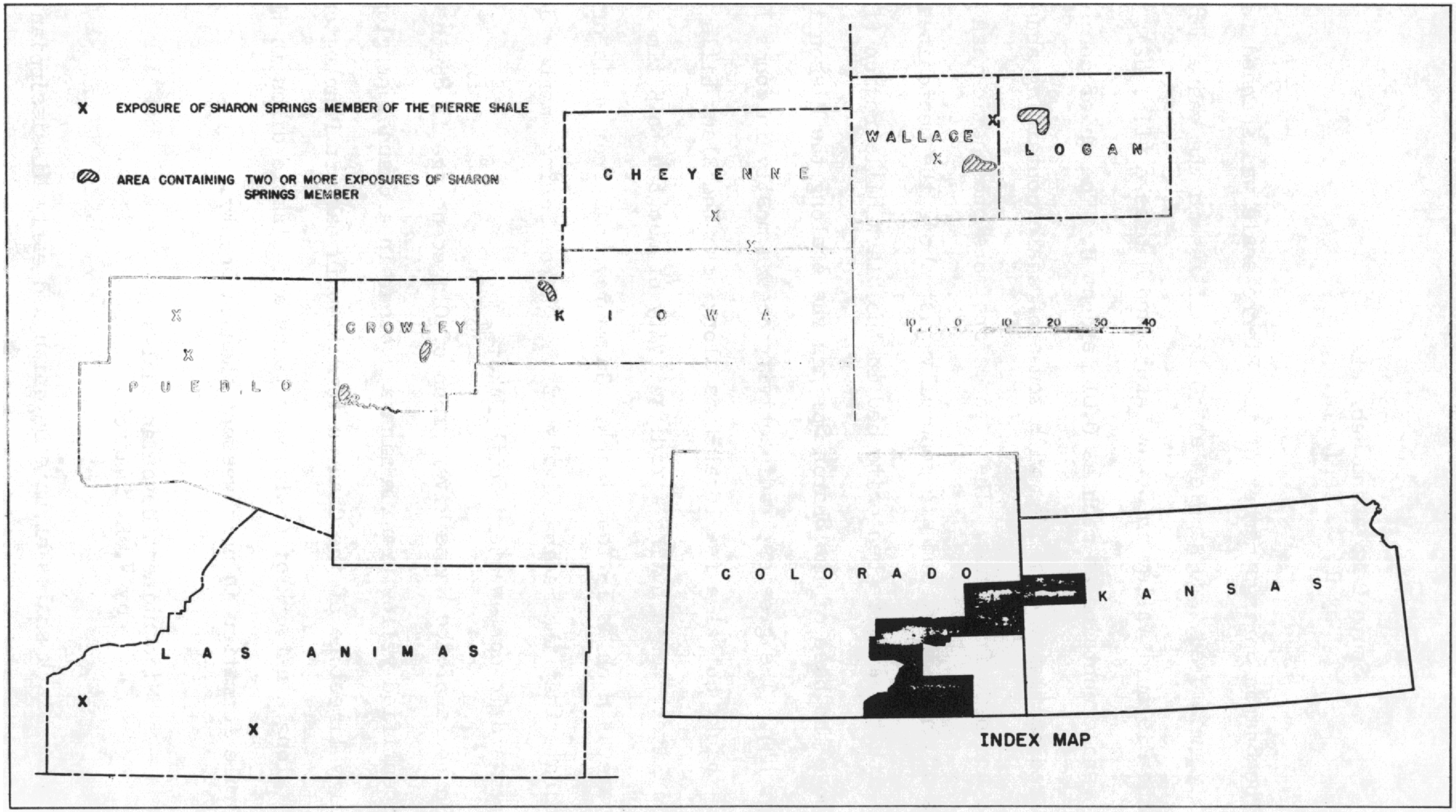

FIGURE 41 MAP SHOWING LOCATIONS OF EXPOSURES OF SHARON SPRINGS MEMBER OF THE PIERRE SHALE

South Dakota and Nebraska
by R. C. Kepferle

The Sharon Springs member of the Pierre shale was scanned for radioactivity, measured, and sampled at 30 localities in the eastern Black Hills and the Missouri Valley in South Dakota and Nebraska (fig. 42). In these areas the shale contains as much as 0.01 percent U. The chief concentration of radioactivity coincides with zones of shale containing abundant fish scales and bone fragments. These zones are more phosphatic than the other shale of the member, and are generally just above the bentonites associated with the Ardmore bentonite bed in the Black Hills region (fig. 43), and above the base of the Sharon Springs shale along the Missouri Valley (fig. 44). The greatest radioactivity occurs mostly in zones less than 2 feet thick, but at a few localities along both the Black Hills and the Missouri River, zones having a radioactivity of about 4 to 5 times background are as much as 15 feet thick. Gamma-ray logs from wells drilled for oil indicate that the radioactivity of the Sharon Springs member decreases northward in northwestern South Dakota.

In rocks of the White River group of Oligocene age in South Dakota, unidentified yellow uranium minerals occur in a channel conglomerate and in a silty limestone of the Chadron formation in eastern Pennington County, and along a network of chalcedony veins and clastic dikes in the overlying Brule formation in northwestern Shannon County.

Midcontinent Devonian shales
by V. E. Swanson

Marine black shales of Late Devonian and early Mississippian age in the Midcontinent area are known to contain significant amounts of uranium

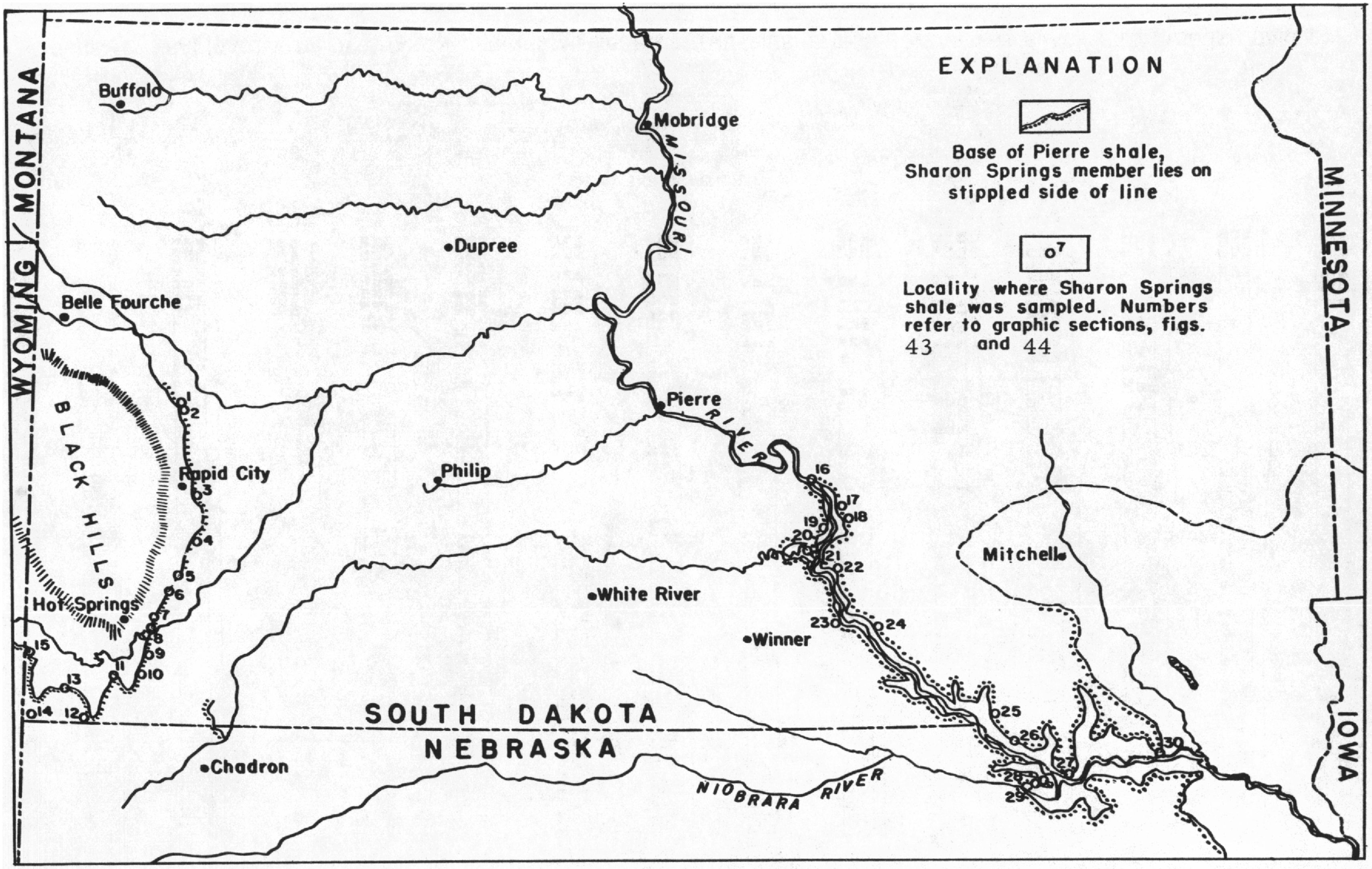

FIGURE 42.--INDEX MAP SHOWING LOCALITIES IN SOUTH DAKOTA AND NEBRASKA WHERE SHARON SPRINGS MEMBER OF PIERRE SHALE WAS SAMPLED

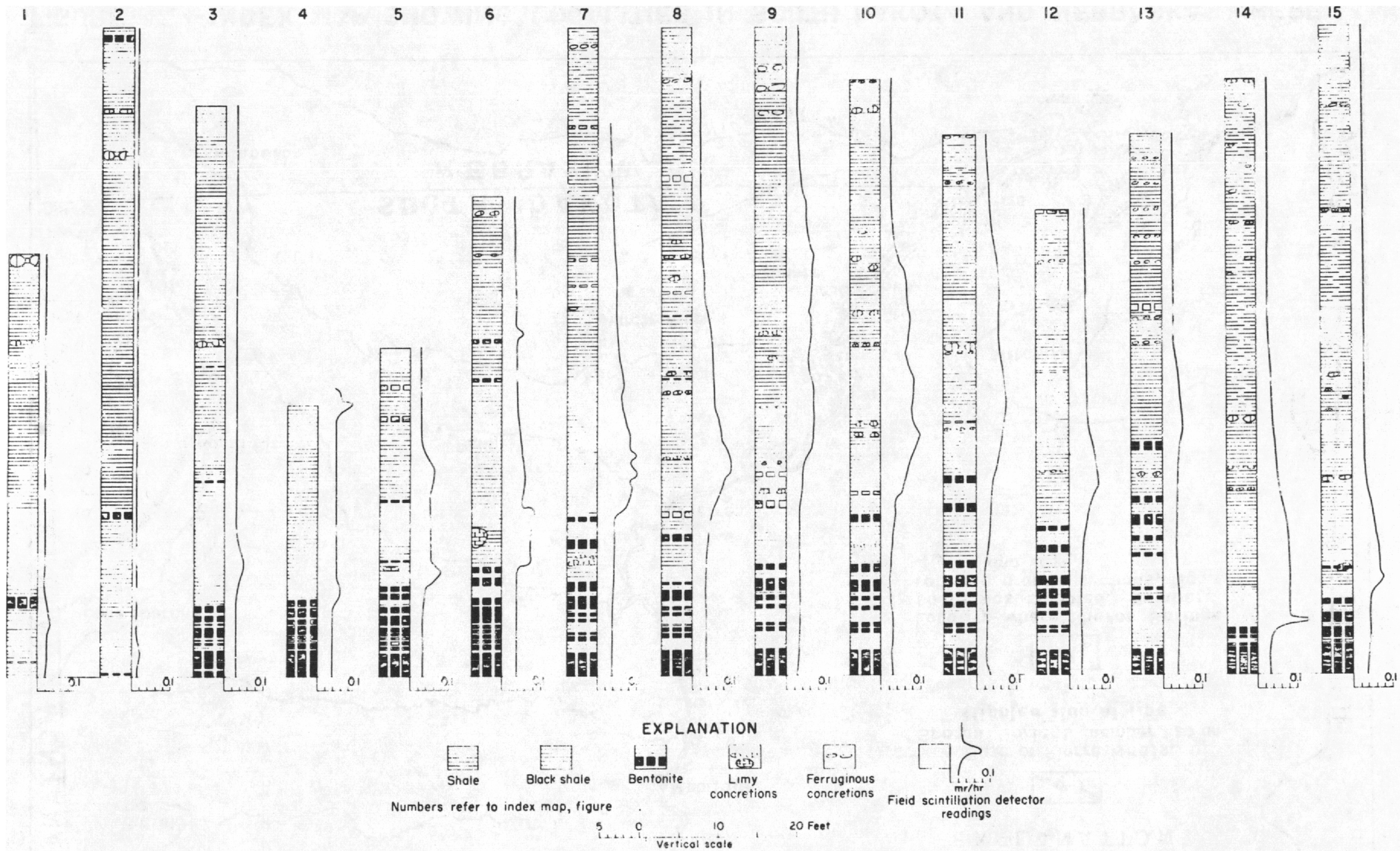

FIGURE 43 --RADIOACTIVITY OF SHARON SPRINGS MEMBER OF THE PIERRE SHALE NEAR THE BLACK HILLS, SOUTH DAKOTA.

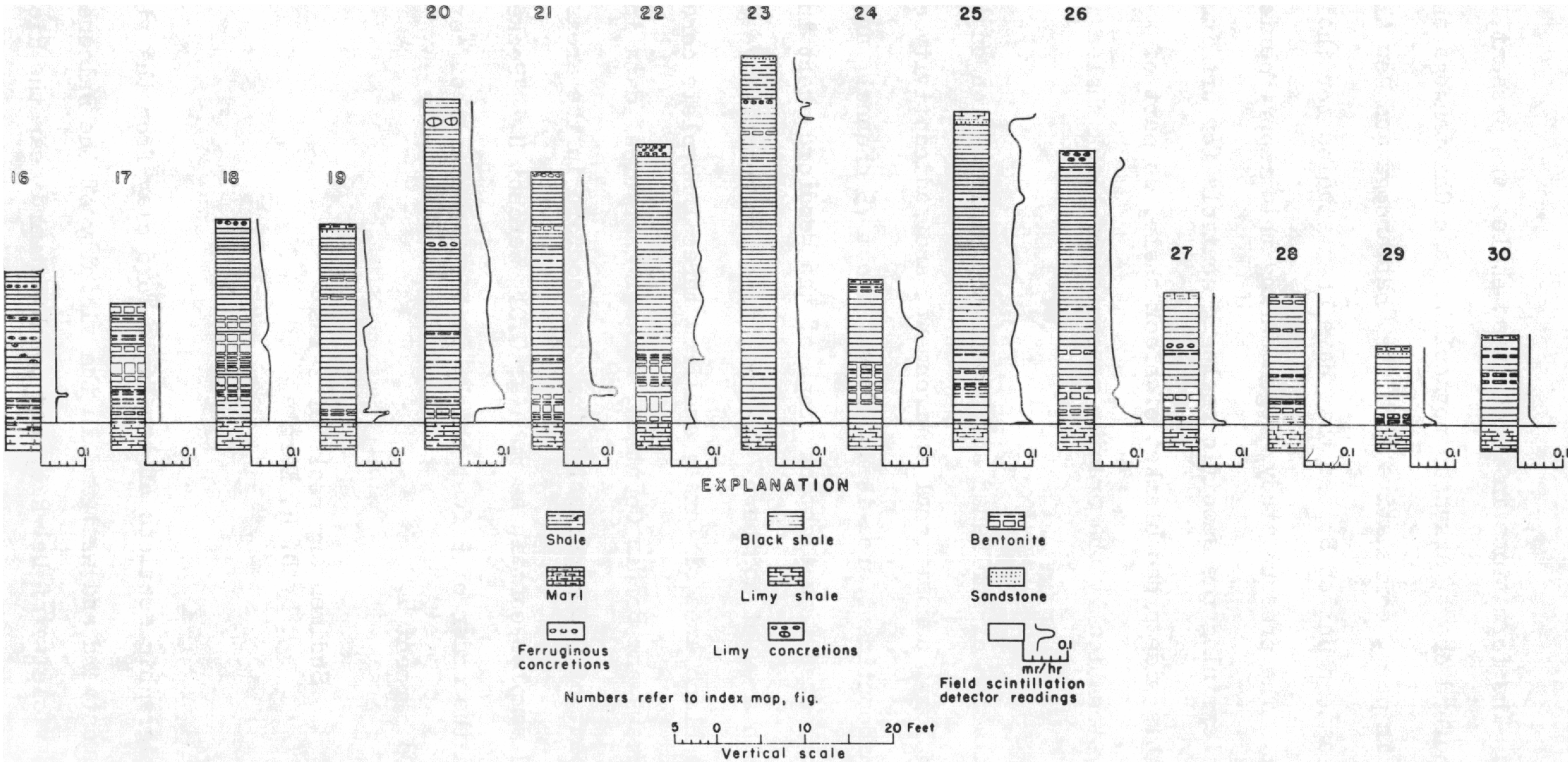

FIG. 44-RADIOACTIVITY OF THE SHARON SPRINGS MEMBER OF THE PIERRE SHALE ALONG MISSOURI RIVER, SOUTH DAKOTA AND NEBRASKA

(Datum plane is the base of Pierre shale) in many places. The formations in which these shales are present, including the Woodford chert, Arkansas novaculite, and Chattanooga shale are, wholly or in part, correlative with the Chattanooga and New Albany shales of the eastern United States that have been studied for their uranium content. The present study, begun during this report period, is aimed toward determining the specific geologic controls for uranium concentration in this widespread blanket of black shale, as part of a program to evaluate systematically the uranium resources of black shales in the United States.

Compilation of published and unpublished information on the distribution, lithology, depositional environment, and radioactivity of these shales in the Midcontinent area is underway. About 75 channel and grab samples were collected from eight outcrops of the Woodford chert in the Arbuckle Mountain area of southern Oklahoma; from the correlative of the Woodford in the Llano area of Texas; and from three incomplete cores of the Woodford in Andrews and Borden Counties, Texas. Analytical data indicate an average content of 0.003 percent U for the Woodford in the areas sampled, though selected samples contain as much as 0.01 percent U. "Pockets" of black shale, on the order of 5 feet thick, in the Llano area of Texas contain about 0.008 percent U.

Sedimentary rocks of Texas
by D. H. Eargle

Eagle Ford clay

Stratigraphic sections of the Eagle Ford clay from the vicinity of Dallas southwestward and westward in the vicinity of the Balcones escarpment to the vicinity of Del Rio, and northwestward near the Rio Grande to the Eagle Mountains in west Texas, were measured, each bed was tested for radioactivity, and beds testing highest in radioactivity were sampled. Nine sections were measured, cores from holes drilled for oil from Milam County on the east to La Salle County on the south were sampled, and radioactivity logs of a number of wells were collected. Water and oil from wells in Caldwell and Guadalupe Counties were also collected. Table 12 is a summary of the analyses of samples from both surface outcrop and well cores received to date from the laboratory. The analyses are grouped according to the lithology of the samples.

Table 12.--Summary of analyses of Eagle Ford clay

	No. samples	Average eU%	Average U%	Maximum eU%	Maximum U%	Minimum eU%	Minimum U%
Surface outcrop							
Claystone*	40	0.002	<0.001	0.003	0.002	<0.001	<0.001
Siltstone**	9	0.001	<0.001	0.001	<0.001	<0.001	<0.001
Limestone	8	0.001	<0.001	0.002	<0.001	<0.001	-----
Bentonite	11	0.002	0.002	0.004	0.005	0.001	<0.001
Well cores							
Claystone	10	0.001	-----	0.003	-----	<0.001	-----
Chalky claystone	16	0.001	-----	0.002	-----	<0.001	-----
Bentonitic claystone	1	0.003	-----				
Limestone	1	0.001	-----				

* Some channel samples include bentonite, siltstone, or limestone.

** Some samples include tuffaceous siltstone.

The samples from the surface outcrop show an average of 0.001 to 0.002 percent eU and generally less than 0.001 percent U. In general, siltstones and limestones show the lowest radioactivity and claystones and bentonites the highest. The maximum recorded content, 0.003 percent eU and 0.002 percent U, is from claystone. Samples from weathered bentonite show a maximum of 0.002 percent eU and 0.005 percent U. Less weathered samples from the same beds show an average of about 0.001 percent eU and 0.001 percent U. These analyses suggest that limited weathering raises the percentage of uranium in the bentonite.

Well cores on the average show a slightly smaller percentage of both eU and U than outcrop samples. Individual core samples of claystone and bentonitic claystone show as high as 0.003 percent eU.

The low uranium content of these rocks indicates that at least part of the radioactivity of the formation may be due to other sources than uranium, perhaps K_4O. Additional field investigations, sampling, and analysis will be undertaken at a locality in Brewster County, Texas, where the Boquillas limestone--the Eagle Ford equivalent in that area-- has been found to be unusually radioactive. Further work on the Eagle Ford clay will be limited to the completion of a final report.

Eastern black shale
by J. F. Pepper

Summaries showing available information on distribution, thickness, stratigraphic position, and physical characteristics were completed for the following Devonian shales: the Bell shale in Michigan; the Ohio shale and its equivalents in Ohio and Kentucky; the Sunbury shale in Ohio and Kentucky; the Marcellus shale in New York, Pennsylvania, Maryland, West Virginia, and Virginia; and the shales of Genesee and Naples ages (Geneseo, West River, Harrell, Burket, Genesee, and Millboro) in New York, Pennsylvania, Maryland, West Virginia, and Virginia.

The Marcellus shale has been selected for further detailed study leading to the construction of a map showing thickness and other physical characteristics of the shale in relation to place and time of deposition. The selection was based on the occurrence near the base of the Marcellus shale of a bed of bentonite which, according to Fettke, Oliver, and Martens, can be correlated over a wide area. If the bentonite bed can be correlated as these writers have proposed, it will provide a datum plane such as is not known to exist for any of the other black shales in the eastern United States, with the exception of the Chattanooga. Such a study may show a relationship between the characteristics of the shale and the time and environment of deposition which, in turn, may indicate some of the factors determining the distribution of uranium in black shales.

Chattanooga shale
by W. C. Culbertson and Lynn Glover

Outcrops of the Chattanooga shale were located by driving along roads crossing the belt of outcrop between Bessemer, Ala., and Chattanooga, Tenn. All outcrops were noted on maps, and 51 were measured and described in detail. Scintillation counter readings were recorded for each section.

The Chattanooga shale in the area investigated unconformably overlies several formations of Silurian and Devonian age, and is everywhere overlain by the Mississippian Maury formation. In a few of the easternmost exposures, notably in the Birmingham area, the Chattanooga is absent but in every exposure the Maury formation was found at its proper interval. The thickness of the Chattanooga shows greater variation in the southern Appalachians than it does farther west in the Cumberland Plateau.

Silt and sand are often prominent constituents of the shale in this region. At the west entrance of the Tennessee, Alabama & Georgia Railroad tunnel northwest of Lafayette, Walker County, Ga., the black basal sandstone of the Chattanooga has the unusual thickness of 4 feet. Another section in a road cut near Blanche, Cherokee County, Ala., has an 18-foot interval of black silty shale and sandstone. Because of slumping much of the sand and silt in this section is in the form of slump balls and stringers. The original bedding is largely destroyed and the shale at the outcrop has a massive appearance.

At many outcrops where the scintillation counter readings are lower than average the Chattanooga shale contains rock believed to be phosphatic. The rock occurs as thin beds as much as 0.2 foot thick which are generally scattered throughout the section. Superficially they resemble the more common siltstone beds of the Chattanooga; closer examination, however, reveals that the rock has many of the lithologic characteristics of the phosphatic nodules found in the Maury and elsewhere in certain intervals of the Chattanooga. These beds have a wide distribution in northeast Alabama and northwest Georgia. Considering the high-phosphate-low-uranium ratio established by earlier USGS work on the Eastern Highland Rim of Tennessee, the chances of finding favorable concentrations of uranium in the shale in much of northeast Alabama and northwest Georgia would be considerably reduced.

At a road-cut on Little Ridge, 15 miles north of Fort Payne, Ala., and half a mile west of a lake and sharp bend in U. S. highway 11, a scintillation counter reading four times the normal for the Chattanooga in that area was obtained. The immediate area of high radioactivity was covered but trenching revealed what seems to be intensely faulted and leached Chattanooga shale. It is believed that some type of secondary enrichment is responsible for the unusually high reading.

Asphaltite and petroleum

Asphaltic rocks in western states
by W. J. Hail, Jr.

Reconnaissance for uranium in asphaltic rocks involved examination and sampling of deposits in Wyoming, Montana, and Missouri. The map, figure 45, shows the location of sampled localities. None of the localities contains above-normal radioactivity. A total of 54 samples, 14 from Wyoming, 4 from Montana, and 36 from Missouri, was collected.

Chemical analyses have been received for nine more samples of those collected during the 1953 field season. Only six samples contain significant amounts of uranium.

Table 13.--Analyses of uranium-bearing asphaltic rocks

Field No.	% oil	% ash in oil	% U in oil ash	Description and location
HNM-4	5.12	1.3	0.012	Grab sample. Asphaltic sandstone. N. Mex. Construction Co. Quarry No. 3, Guadalupe Co., N. Mex.
HU-13	6.9	1.6	0.012	Grab sample. Asphaltic sandstone in middle of 50' bed. About 6 miles north of Sunnyside, Carbon Co., Utah.
HU-15	5.5	3.6	0.010	Grab sample. Asphaltic sandstone in middle of 25' bed. About 6 miles north of Sunnyside, Carbon Co., Utah.

(Table 13.--Continued)

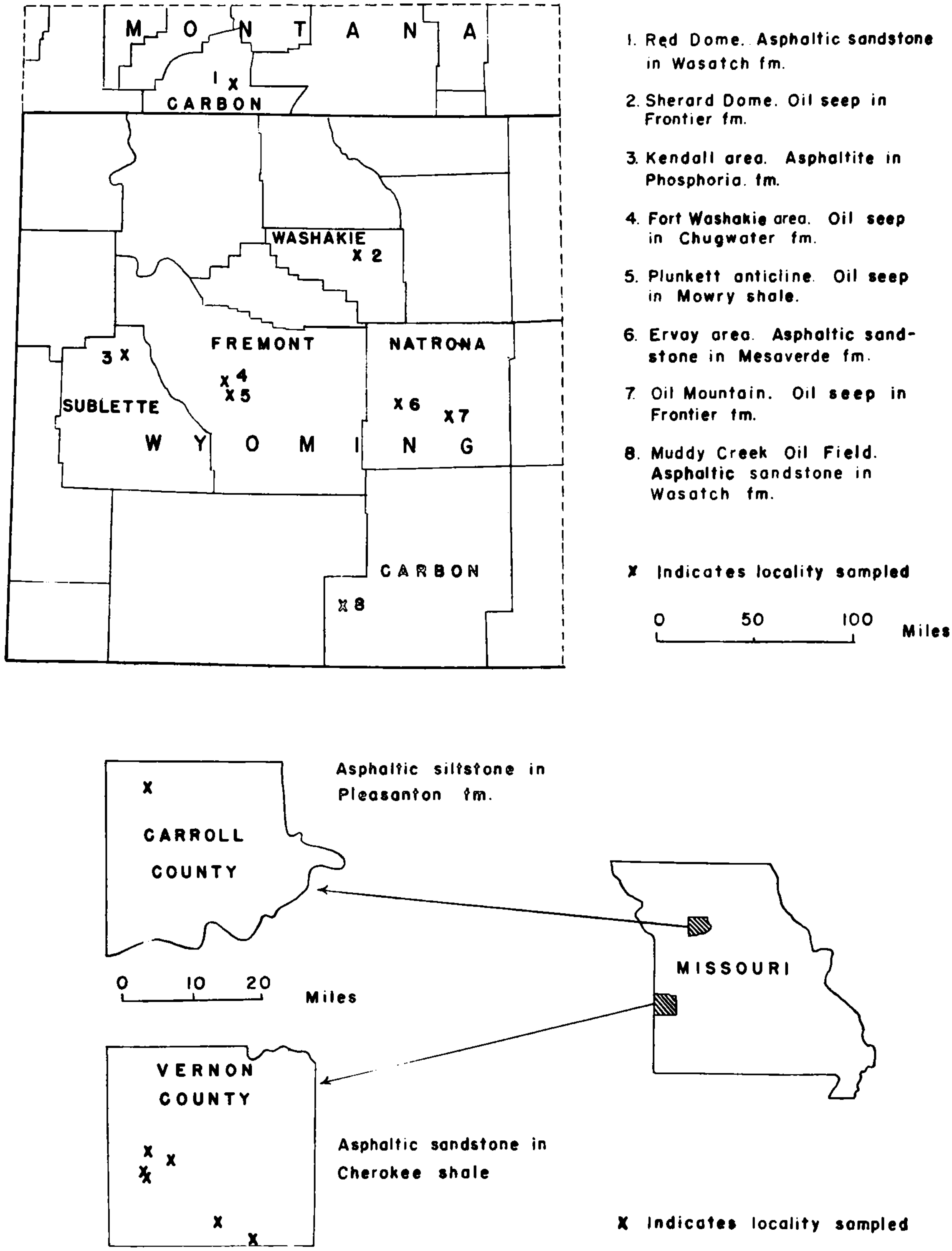

FIGURE 45 INDEX MAP SHOWING LOCALITIES SAMPLED FOR URANIUM-BEARING ASPHALT IN MONTANA, WYOMING, AND MISSOURI

Table 13.--Continued

Field No.	% oil	% ash in oil	% U in oil ash	Description and location
HU-29	9.6	0.3	0.015	Grab sample. Asphaltic sandstone. Near top of 82' bed. About 6 miles north of Sunnyside, Carbon Co., Utah.
HU-63	1.4	2.5	0.013	Grab sample. Asphaltic sandstone. Lower part of 12' bed. About 5 miles west of Vernal, Uintah Co., Utah.
HU-69	7.0	1.5	0.015	Grab sample. Asphaltic sandstone. Middle of 19' bed. About 5 miles west of Vernal, Uintah Co., Utah.

Geochemistry and petrology

Geochemistry of uranium-bearing carbonaceous rocks
by I. A. Breger and Maurice Deul

Uraniferous coals

Continuation of interpretative studies of the organo-uranium compounds isolated from weathered coals has led to the conclusion that the uranium is not associated with any particular, relatively simple type of organic component in the coal. Rather, it appears to be retained in the coal by substances very similar to humic acids in composition, probably as the ionic compounds, uranyl humates.

The uranyl-humic compounds that were isolated from weathered coals contained percentages of oxygen slightly higher than those in most humic acids. This "excess" oxygen undoubtedly reflects the weathered nature of the coal. No particular organic compound is responsible for the retention of uranium in coals; coals, especially those of low rank, have the ability to react with and retain uranium. This conclusion is of interest in the search for uraniferous coals.

Isolation of a large quantity of uranium-bearing organic material from unweathered lignite from S. Dak. is nearly complete. Sufficient material is being isolated to enable its characterization and comparison with isolates previously obtained from weathered coals.

Colorado Plateau studies

An oil-impregnated sandstone collected from the North workings, Temple Mountain, was extracted and fractionated to establish the distribution of uranium in the asphaltenes, the asphaltene-free oil, and the extracted, oil-free sandstone. The oil contained 0.0000455 percent U and the asphaltenes isolated from the oil contained 0.000147 percent U or approximately 76.3 percent of the uranium in the oil. The sandstone from which the oil was extracted contained 0.00020 percent U. It was concluded from these data that the oil in the sandstone contained a maximum of 30 percent of the uranium present in a possible marine source bed for petroleum (Breger, unpublished data) and probably carried this uranium out of the shale during the period of expression.

In contrast, an analysis of an oil seeping through the walls of an operating mine in the North workings, Temple Mountain, shows 0.00343 percent U, an extraordinarily high percentage. Asphaltenes isolated from the oil carry 78.1 percent of the uranium in the oil.

Studies of the oil-impregnated sandstone and of the oil from the oil-seep indicated that oil, on migration through a uraniferous zone, can pick up and carry uranium, but that oil which has not penetrated a uraniferous zone carries only a "normal" percentage of uranium. The low percentage of uranium in the oil from the oil-impregnated sandstone may indicate that the impregnation occurred prior to the introduction of uranium in the Temple Mountain area.

Infrared absorption studies of the asphaltenes from the two oils showed them to be fundamentally similar and also indicated that they contained carboxyl (⁻COOH) groups. These groups may be responsible for the retention of uranium by the asphaltenes.

A carbonaceous sandstone was studied to establish the association of uranium with the carbonaceous material. The ore is black and has a petroliferous odor when freshly broken. Upon extraction with a wide variety of organic solvents only 0.09 weight percent of soluble material was removed. When recovered, the extractable material has an appearance and odor similar to that of crude oil. The extracted ore has an organic carbon content of 20.49 percent.

Using the technique of ball-mill grinding in mixed media that was developed in the study of black shales, the ore was separated into organic- and mineral-rich fractions and two middling fractions. Data for the four separates and for the original ore are given in table 14.

Table 14.--Analyses of fractions of carbonaceous sandstones

	Ash, %	C, %	H, %	U, %
Original ore	72.46	20.49	1.53	2.4
Organic separate	18.01	62.63	4.01	1.1
Mineral separate	95.35	1.92	0.35	0.63
Organic middlings	83.16	12.69	1.24	1.1
Inorganic middlings	88.38	9.05	1.22	4.9

Several observations can be made from the data:

(A) The uranium is not now associated with the carbonaceous matter. If the uranium has been associated with the carbonaceous matter, a separation has since taken place.

(B) The uranium is not associated with the mineral components of the ore. If the uranium were present as a coating on the mineral grains, then fine grinding might have stripped the coating so that

(C) The highest percentage of uranium is now found in the fraction containing mineral particles which are ground to colloidal or nearly colloidal size.

A possible explanation to account for the experimental data is the following:

The sandstone at one time may have been impregnated with oil. Aqueous solutions may have forced the oil out of the sandstone leaving behind only the trace responsible for the asphaltic odor of the rock. Humic matter and uranium subsequently saturated the pores of the sandstone and the organic matter became metamorphosed to its present state.

The organic material now has a chemical composition strongly suggestive of lignite. The composition of the material, moreover, is such as to almost definitely preclude a petroliferous origin. If organo-uranium compounds were present, irradiation, primarily by alpha particles from the uranium and its daughter products, may have broken the uranium-organic bonds thereby freeing the uranium from the carbonaceous material. This hypothesis is under investigation.

Studies of small, carbonaceous pellets from the Shinarump formation were continued. Available pellets were isolated, cleaned of adhering mineral matter, and separated on the basis of specific gravity (1.29 to 1.56). Insufficient material for all projected studies is available and more pellets are being collected.

Mineralized and coalified log fragments were selected for mineralogic and chemical analysis. This material, which corresponds to vitrain, is being investigated to determine if the uranium is retained in the same manner that it is held in massive coals that already have been studied.

Black, vitreous carbonaceous material (1/8" to 5/8" thick and up to several feet long) that occurs sporadically in the Chattanooga shale in Tennessee and in the Cleveland shale in Ohio was studied in detail. This material was reported as "bituminous" or "asphaltic" lenses or stringers in descriptions of these Upper Devonian black shales. Microscopic study of the material by J. M. Schopf of the USGS has revealed the structure of coalified woody plant tissue similar to vitrain. Some of this material shows sufficient detail to be referable to the genus Callixylon.

A relatively large sample of the vitrain from Cannon County, Tenn. was available for standard coal analyses and was found to contain unusually high percentages of uranium, germanium, vanadium, and nickel.

The association of uranium or germanium with coalified logs or coalified woody debris has long been known. The association of both uranium and germanium, such as has been found in this and other specimens from Tennessee and Ohio, has not previously been reported.

Coal petrology
by J. M. Schopf, R. J. Gray, and C. J. Felix

Petrologic investigations included a study of Dakota uraniferous lignite and preparation of a report on the associations of uranium in a core sample of sub-bituminous coal from the Red Desert in south central Wyoming.

Uranium-bearing coals from the Dakotas differ in some respects from those of the Red Desert in Wyoming or the Goose Creek district in Idaho.

The former are banded coals and evidently originated principally from vegetation growing essentially in situ, whereas the coals of the Red Desert and Goose Creek district appear to contain a much greater proportion of transported organic material. The most uraniferous layers of the Idaho and Red Desert occurrences both appear to contain unusually large percentages of amorphous waxy matter; this is lacking in the Dakota occurrences. The Idaho and Red Desert coals also lack the normal top-preferential pattern of uranium occurrences that characterizes most of the Dakota coal. Although position within the coal bed is evidently a most important factor in the Dakota occurrences, in all three districts it appears that the more highly decayed and finely particulate plant debris (translucent attritus) is generally greatest in layers having the highest uranium content. A factor that seems too frequently repeated to be coincidental is association of uranium with a layer high in detrital mineral matter (clayey and silty beds or partings) above layers of greatest uranium content.

Current laboratory studies have been devoted mainly to coals from the Slim Buttes district in South Dakota. Within the Slim Buttes area, proper, six coal beds are locally represented (TEI-390, p. 131-136 and TEI-440, p. 113-117). The three principal beds are the Mendenhall Rider, the Mendenhall and the Olesrud, each of which includes two or more "benches" defined by prominent and fairly persistent partings. The "benches" are designated for purposes of this report as "upper" and "lower" parts of the named coals, as follows:

	Maximum thickness observed in cores	
Upper Mendenhall Rider	up to 10.39 feet	(hole SD-8)
Lower Mendenhall Rider	up to 8.04 feet	(hole 16)
Upper Mendenhall bed	up to 5.29 feet	(hole SD-19)
Lower Mendenhall bed	up to 7.78 feet	(hole 3)
Upper Olesrud bed	up to 6.93 feet	(hole SD-19)
Lower Olesrud bed	up to 5.69 feet	(hole SD-8)

Paleontologic studies confirmed field identification of the major coal beds. Water fern megaspores are abundant in the Lower Olesrud bed, but are scarce or absent in the coal beds higher in the sequence.

The average petrologic composition of each coal in Slim Buttes is given in table 15.

Table 15.--Average petrologic composition of coal beds in the Slim Buttes area, Harding County, S. Dak.

	Anthra-xylon	Transl. Attritus	Opaque Attritus	Petrog. Fusain	Visible Impurity
Upper Mendenhall Rider 1/	60.0	29.6	1.6	7.8	1.0
Lower Mendenhall Rider	47.5	34.5	5.5	7.0	5.6
Upper Mendenhall Bed	47.3	43.2	3.8	4.6	1.1
Lower Mendenhall Bed	53.3	35.7	4.1	5.5	1.5
Upper Olesrud Bed	51.0	35.6	4.0	5.6	3.7
Lower Olesrud Bed	53.3	33.4	3.4	4.8	5.1
Total Average Slim Buttes beds	51.2	36.4	3.0	5.5	3.0
Average of six beds of lignite mined in N. Dak. (U.S. Bur. Mines Info. Circ. 7691, p. 66, 1954)	58.1	30.0	8.6	3.3	-

1/ About half of the Upper Mendenhall Rider Bed was lost in drilling: figures for both Upper and Lower Rider beds are based on complete coverage of all coal recovered from hole SD-8. Values given for other beds all are based on averages of three to five different coal-bed samples.

The weathered coal at the Mendenhall mine appears to be of different nature from the unweathered coal from the same bed in adjacent deep drill holes. The weathered coal contains less anthraxylon but more translucent attritus and opaque attritus than the unweathered coal. A comparison of these constituents of the Upper Mendenhall coal bed, extending from 333.83 to 339.12 feet in depth in hole SD-19, with the same part of the Upper Mendenhall coal bed at the strip mine is shown below. All numerical values represent percentages.

	Anthra-xylon	Transl. Attritus	Opaque Attritus	Petrog. Fusain	Visible Impurity
Fresh coal, Hole SD-19	48.6	39.7	4.9	5.7	1.1
Weathered coal, Mendenhall strip mine	6.4	62.2	13.2	15.6	2.6

The petrologic constituents and their subordinate components for four uraniferous samples of the upper part of the Upper Mendenhall coal from hole SD-19 is shown in table 16. The component composition of only the translucent attritus of these same four samples is shown in table 17. The samples are arranged in order, TE-4 at the top of the coal to TE-7 which is one feet below top of the coal.

Geochemistry of uranium-bearing shales
by Maurice Deul and I. A. Breger

Samples of Chattanooga shale, of vanadium shale from the Phosphoria formation in Wyoming, and of shale from the Dakota formation near Gallup, New Mexico were fractionated by ball-mill grinding in mixed media. These shales were chosen because they represent different geological environments and contain different percentages of uranium. All the shales have about the same percentage of organic material. Preliminary results, reported in TEI-440, indicate that uranium is present in the Chattanooga shale as a separate colloidal phase disseminated through the organic matrix but not combined with the organic material. Complete data are shown in table 18.

Table 16.--Composition, in percent, of the four uraniferous coal layers at the top of the Upper Mendenhall coal bed in hole SD-19

Constituents or components	TE-4	TE-5	TE-6	TE-7
Anthraxylon:				
Coarse	11.10	12.90	40.45	43.84
Attrital	23.61	27.13	18.42	14.10
Total	34.71	40.03	58.87	57.94
Translucent attritus:				
Sub-anthraxylon	1.90	2.02	2.42	1.54
Humic degradational matter	46.93	38.86	35.56	30.13
Total	48.83	40.88	37.98	31.67
Red attrital resins	0.24	0.22	0.19	0.10
Cuticle	0.02	0.01	0.01	0.0
Spores	0.20	0.11	0.05	0.06
Yellow attrital resins	0.02	0.10	0.0	0.07
Waxy amorphous	0.27	0.49	0.12	0.18
Total	.51	.71	.18	.31
Fungal phyterals	0.03	.0	.0	.0
Brown matter	6.67	2.62	0.95	1.86
Total translucent attritus	56.28	44.43	39.30	33.94
Opaque attritus	3.44	12.77	1.23	3.65
Microfusain	2.58	2.19	0.40	2.33
Megafusain	1.64	.0	.0	1.71
Total	4.22	2.19	0.40	4.04
Disseminated pyrites	0.24	0.15	.0	0.12
Transparent minerals	0.15	0.21	.0	0.21
Clayey minerals	0.96	0.23	0.21	0.11
Total	1.35	.59	.21	.44
TOTAL	100.00	100.01	100.01	100.01
Percent uranium	.0235	.0160	.0130	.0060

Table 17.--Composition, in percent, of translucent attritus in uraniferous coal layers at the top of the Upper Mendenhall coal bed in hole SD-19

Component	TE-4	TE-5	TE-6	TE-7
Subanthraxylon.............	3.38	4.55	6.16	4.53
Humic Degradational matter.	83.39	87.48	90.48	88.80
Total..................	86.77	92.03	96.64	93.33
Red attrital resins........	0.43	0.49	0.49	0.29
Cuticle..................	0.04	0.02	0.02	.0
Spores....................	0.35	0.24	0.13	0.17
Yellow attrital resins.....	0.04	0.23	.0	0.20
Waxy amorphous............	0.48	1.10	0.31	0.52
Total..................	0.91	1.59	0.46	0.89
Total fungal phyterals.....	0.05	.0	.0	.0
Total.....................	100.01	100.01	100.00	100.01
Percent of layer represented by translucent attritus....	56.28	44.42	39.30	33.93
Percent uranium chem. determined..........	.0235	.0160	.0130	.0060

Table 18.--Composition of fractions, black shales

	Original sample	Organic separate	Mineral separate	Middlings	Refined organic separate	Refined mineral separate
Ash, percent	75.5	68.1	80.1	66.1	32.3	83.6
Uranium, percent	0.0090	0.0059	0.0049	0.019	0.0038	0.0035
Carbon, percent	13.72	17.00	9.5	9.07	40.0	4.7
Hydrogen, percent	1.57	1.95	1.5	2.77	4.2	1.4

The refined separates were obtained by grinding the original organic and mineral separates a second time. The "middlings" represent the finest material obtained in grinding. Most of the particles in this fraction are colloidal or nearly colloidal in size.

Similar fractionation of the vanadium shale from the Phospheria formation, Coal Canyon, Wyoming, leads to conclusions identical to those reached for the Chattanooga shale. Data for the vanadium shale are shown in table 19.

Table 19.--Composition of fractions, Phosphoria formation

	Original sample	Organic separate	Mineral separate	Middlings
Ash, percent	76.6	26.4	85.0	81.1
Uranium, percent	0.0039	0.0013	0.0032	0.0048
Carbon, percent	14.39	51.1	2.75	9.0
Hydrogen, percent	1.6	2.35	1.3	1.5

Fractionation of the shale from the Dakota formation, New Mexico, leads to conclusions contrasting sharply with those for the Chattanooga and vanadium shales. Analysis of fractions from the Dakota shale (table 20) show that the uranium is retained by and associated with the carbonaceous constituents, and is not present as a separate phase.

The organic concentrate from the Chattanooga shale exhibits no unusual trace element enrichments. In contrast, the organic fraction from the Phospheria formation contains striking enrichments of nickel, vanadium, copper, silver, and molybdenum; and the organic concentrate from the Dakota shale contains notable enrichments of copper, lead, cerium, and lanthanum.

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Table 20.--Composition of fractions, Dakota shale

	Original sample	Organic separate	Mineral separate	Middlings
Ash, percent	76.3	30.2	90.0	67.8
Uranium, percent	0.091	0.41	0.005	0.12
Carbon, percent	12.97	48.5	0.82	13.8
Hydrogen, percent	1.62	2.98	1.6	2.25

Fine grinding of the Chattanooga shale, followed by air elutriation, also was applied to the study of the relationship of uranium to other shale components. While these studies were preliminary in nature, the results have been interpreted as confirming the conclusions already stated for associations in the Chattanooga shale.

The fractionations shown in tables 18, 19, and 20 are superior to any which have been published or with which project members are familiar. The data obtained have clarified a number of points with regard to the mechanisms responsible for the precipitation of uranium in carbonaceous shales. These conclusions now await confirmation.

Asphaltite and petroleum
by A. T. Myers

During the report period 168 chemical determinations on 116 samples and 7,336 semiquantitative spectrographic determinations for 126 samples were completed. A distribution by constituents and sample types is shown in table 21.

Analyses of the crude oil samples supplied by H. J. Hyden have been completed with the exception of 74 determinations. These samples were selected to give wide areal and geologic coverage.

Table 21.--Distribution by sample types and constituents

Sample Type		No. of Samples
Petroliferous Rock		19
Crude Oil		51
Asphaltite		2
Miscellaneous (coals, shale, etc.)		44
	Total	116

Constituents		No. of Determinations
% Ash		101
% U in Ash		41
% Oil		19
Other 1/		7
	Total	168

1/ Including % arsenic, % organic matter.

The paper entitled "The association of uranium and other metals with crude oils, asphalts, and petroliferous rocks," TEM-513, by Ericksen, Myers, and Horr was published in the October Bulletin of the American Association of Petroleum Geologists.

The major portion of the work during the report period was directed toward an evaluation of the losses of uranium and accompanying metals during the ashing of crude oil, asphalt, and asphaltite. The ashing of the sample is carried out in a vycor-type combustion tube in a three element electric combustion furnace. A slow stream of oxygen is passed over the sample to support combustion. All products evolved during the ashing are bubbled through a warm 15 percent nitric acid solution which acts as a scrubber. With liquid samples, 25 mg. of a previously analyzed pure quartz powder is added to act as a collector for the small quantity of ash. A like amount of quartz is added to the scrubber solution for the same purpose. This addition of quartz greatly simplifies the spectrographic analysis of the samples.

Results to date indicate that when loss of uranium during ashing is detected, the amount of the loss becomes a function of the original uranium content of the sample. Different types of crude oils and asphalts present different problems. Certain types of crude oils may be ashed with little or no loss of metals, while other types may show significant loss of uranium and other metals during ashing. An asphaltite sample prepared from a bulk sample of asphaltic uranium ore from New Mexico had a uranium content of 27,500 ppm in the sample as determined by wet ashing. The sample, which was 8.498 percent ash, had 294,660 ppm U in the ash while the scrubber solution from the sample had 4.1 ppm U on a sample basis. A sample of crude oil from California was found to contain 46.05 ppm U in 0.0411 percent ash. The scrubber solution from this sample contained 0.1 ppm U on a sample basis.

Spectrographic analyses on duplicates of the above samples show small losses of vanadium, cobalt, lead, and nickel on dry ashing. The loss of copper is moderate. There is no detectable loss of arsenic.

The uranium content is highest in asphaltite pellets and similar material high in components insoluble in organic solvents. It may be that the high uranium content in these materials is responsible for their insolubility. Other metallic elements such as nickel and vanadium generally parallel this distribution.

In petroliferous rocks the metals, including uranium, follow the extracted oil. A study was made of the ratio of metal contents of the extracted oil and of the rock residue. In the 11 samples studied the metals were concentrated to a greater extent, almost 2:1, in the extracted oil, with one exception. Microscopic examination of this rock residue showed that the sand grains were coated with a black, lustrous material in which the metals were assumed to be concentrated. Examination of the other residues, in which the extract contained the metals, showed clean fragments with no coating. This leads to the conclusion that the metals are in colloidal suspension in the oil or contained as metalo-organic complexes.

The data indicate that in general the amount of uranium and other metals is higher in asphaltic crude oils, asphalts, and asphaltites than in paraffinic or aromatic crude oils. These data, while not complete for all the areas studied, show that oils of low API gravity from certain areas are high in uranium. In addition certain Wyoming oils from Pennsylvanian and Permian-age rocks seem to have low API gravity and are characteristically high in nickel and vanadium.

Research is underway on methods of separation for naphthenic acids and other possible uranium complexing compounds present in the nitrogenous fractions of crude oil.

Uranium in western petroleum
by H. J. Hyden and N. W. Bass

A total of 147 samples of crude oil, 41 samples of oil field brine, and 16 samples of oil refinery residua has been collected from oil-producing areas in 14 states. This total includes 32 oil samples and four states in addition to those reported previously. The four new states are California, South Dakota, North Dakota, and Nevada.

Oil samples

The oil samples are first ashed; the ash from the samples is then subjected to radiometric, chemical, and spectrographic analyses. A total of 49 samples has been tested for equivalent uranium content. Uranium content has been determined for 12 samples, and seven of these have also been tested for equivalent uranium content. The ratio of U to eU is 1.17 for one sample; the ratio for the remaining samples ranges from .175 to .005.

Table 22.--Summary of petroleum samples tested

	No. of samples	% eU in ash
	5	<.0010
	44	.001 - .032
Total	49	

Samples tested for uranium content

	No. of samples	% U in ash
	1	<.0001
	11	.0001 - .007
Total	12	

The ash from 75 oil samples has been tested by spectrographic analyses for 60 elements. The following elements are present in one or more samples in quantities of 0.01 percent or more of the ash: Al, Fe, Mn, Ti, Ca, Mg, Na, K, As, Ba, Ce, Co, Cr, Cu, Ge (in one sample only), Li (in oné sample only), La, Nd, Ni, Pb, Sn, V, Y (in one sample only), Zn, and B. The following elements are present in one or more samples as

1 percent or more of the ash: Ca, Mg, Na, K, Cu, Ni, Pb, V, and Zn. Vanadium, copper, and nickel are common major constituents.

Duplicate samples of each oil sample being tested for metal content are subjected to Hempel analysis and sulfur and nitrogen analysis by the U. S. Bureau of Mines. To date, 18 Hempel analyses, 18 sulfur analyses, and 16 nitrogen analyses have been completed.

Brine samples

Oil field brines will be analyzed chemically. No analyses of water samples have been completed at this time.

Refinery residua

The 16 samples of oil field residua are from 10 refineries in Wyoming, Montana, Texas, and Oklahoma. Trace metal analyses have been completed for 14 samples from nine refineries. These are shown in table 23.

Table 23.--Trace metal analyses of oil-field residua

Location of refinery	Source area of crude oil	Material	% Ash	% U in ash
Sinclair, Wyo.	Wyoming	No. 6 fuel oil	0.012	0.0006
Sinclair, Wyo.	"	asphalt	0.022	0.0004
Casper, Wyo.	Wind River Basin, Big Horn Basin, Wyo.	coke	0.425	0.024
Casper, Wyo.	Salt Creek field, Wyo.	coke	0.126	0.023
Casper, Wyo.	Wyoming	coke	0.120	0.015
Laurel, Mont.	Williston Basin, Mont., N. Dak.	asphalt	0.033	0.0001
Cody, Wyo.	Oregon Basin field, Wyo.	asphalt	0.026	0.0003
Cody, Wyo.	Elk Basin field, Wyo.	asphalt	0.049	0.0005
Cody, Wyo.	Oregon Basin field, Pitchfork field, Half Moon field, Wyo.	asphalt	0.072	0.0004
Thermopolis, Wyo.	Hamilton Dome, Wyo.	asphalt	0.074	0.0004
Tulsa, Okla.	Central and eastern Oklahoma	asphalt	0.014	0.0003
Tulsa, Okla.	Central and eastern Oklahoma	asphalt	0.028	0.0007
Tulsa, Okla.	Osage and Tulsa Counties, Okla.	asphalt	0.024	0.0007
Stroud, Okla.	Laffoon field, Prague field, Okla.	asphalt	0.058	0.001

URANIUM IN PHOSPHATES

Northwest phosphate
by V. E. McKelvey

Work on the Northwest phosphate program during the report period consisted mainly of geologic mapping, stratigraphic studies (including a field conference on the nomenclature of Permian rocks of the phosphate field), and the preparation of reports. The results of the conference on nomenclature will be reported later when the plan evolved is approved by the Committee on Geologic Names. Other results are summarized below.

Geology of the Soda Springs quadrangle, Idaho
by F. C. Armstrong

This project was resumed in September after a 4-year recess. About two square miles were mapped during the fall.

Two volcanic cones were mapped on the crest of the north end of the Bear River Range. Porphyritic basalt flows from the cones flowed down pre-existing valleys on both sides of the range. This porphyritic basalt is the youngest of a differentiated series of basalt flows in the Soda Springs quadrangle.

Work completed to date shows that: (1) The klippe formerly mapped on Three Mile Hill does not exist. There is thus no evidence that the thrust extends across Bear Lake Valley. (2) Block faults are much more abundant than thought previously. (3) The gross structure of the Bear River Range is the west limb of a northwesterly plunging syncline cut by numerous faults. (4) The structure of the Soda Springs Hills is the same as that of the Bear River Range except that faults are more numerous and complex.

Geology of the Snowdrift Mountain quadrangle and adjacent areas, Idaho
by E. R. Cressman

Five square miles in Snowdrift Mountain quadrangle and 20 square miles in the northeastern and north-central parts of the Montpelier quadrangle were mapped. The area consists of a folded and faulted mass of upper Paleozoic and Triassic sedimentary rocks that are in fault contact with Jurassic rocks on the east, south, and west. The older rocks were interpreted by Mansfield as being part of the Bannock overthrust sheet, the fault surface here forming a gentle north-plunging syncline. The structure of this area and of the Georgetown Canyon area immediately to the northwest constitutes the main evidence for interpreting the Bannock fault as a folded low-angle overthrust.

Detailed mapping has demonstrated that the fault trace is not continuous. The fault bounding the older rocks on the east dies out southward, and the southern boundary fault branches eastward into several small thrusts that in turn die out. All of the thrusts are either steeply or moderately dipping.

Geology of the Stewart Flat quadrangle, Idaho
by L. D. Carswell and R. P. Sheldon

About one-half of the quadrangle was mapped during the field season. In the southern half of the quadrangle about 9 square miles have been mapped, 9 can be completed by photogeologic methods, and 9 remain to be mapped. Mapping of the northern half of the quadrangle is in approximately the same stage of completion.

Mapping has demonstrated that the structure is more complicated than indicated by Mansfield and co-workers. In the southern half of the quadrangle, a considerable area of the axis of the Webster syncline is underlain by the Thaynes formation. This means that the Phosphoria lies deeper underground and less minable phosphate lies above entry level than heretofore thought.

Geology of the Phosphoria formation in Montana
by R. W. Swanson

Sections of the Phosphoria formation or parts of it were sampled at Logan, Dissett, Elliston, Anderson Mine, East Gird Creek, Trout Creek, Warm Springs, White Gulch, and Mt. Humbug, Montana. Seventy channel samples of phosphatic rocks were collected. In addition rocks of Phosphoria age in Alberta and British Columbia were examined to obtain information on the paleogeography of the Phosphoria sea.

Near Elliston 5 feet of phosphate rock is overlain by 2 feet or more of fairly phosphatic sandstone; the whole sequence may prove of furnace grade. The rock generally is siliceous and low in organic matter. The Warm Springs phosphate is siliceous and unusually rich in fluorite, apparently mostly secondary; it probably is of good grade and is nearly $4\frac{1}{2}$ feet thick. That at Gird Creek in the Maxville district is diluted by mudstone partings but probably is of furnace grade everywhere and may be of acid grade locally. At Mt. Humbug in the Butte Highlands near Divide an 11-foot section of phosphate, argillaceous or with mudstone partings, is of furnace grade and the top 4 feet may be of acid grade. The rock is black and appears graphitic, perhaps owing to slight metamorphism by igneous activity nearby.

Though good correlation could not be established between the Rocky Mountain formation in British Columbia and Alberta and the Phosphoria formation, several sections of the upper parts of the Rocky Mountain formation were studied, and similarities between the Canadian and Montana stratigraphy - including the presence of phosphate - were sufficient to support the idea that the Rocky Mountain formation of Canada is roughly equivalent to the Quadrant and Phosphoria formations of Montana. Partial sections were measured at four localities.

The Phosphoria formation in north-central Idaho
by E. R. Cressman

Several years ago C. P. Ross reported phosphatic float along Hawley Creek nine miles east of Leadore, Idaho, and 20 miles west of any known outcrops of the Phosphoria formation at this latitude. A visit to the locality in July disclosed the presence of float of high-grade phosphate rock and bedded chert very similar in appearance to the Rex chert member of the Phosphoria. A section measured from the surface exposures showed that the Phosphoria formation is underlain by quartzite similar to that of the Quadrant formation of Montana and is overlain by brown-weathering dark-gray mudstone similar to parts of the Dinwoody formation in southwestern Montana and southeastern Idaho. The Phosphoria consists of about 700 feet of cherty dolomite overlain by 150 feet of bedded chert. Phosphate rock occurs at two horizons, one 80 feet below the bedded chert and the other 140 feet below the chert. The phosphatic zones are very poorly exposed, but the amount of high-grade phosphate rock in the float suggests the possibility of a minable thickness of phosphate.

Geology of the Phospheria formation in Wyoming and east-central Idaho
by R. P. Sheldon

Three sections of the Rex member of the Phospheria formation were measured at Buck Creek and Steer Creek, Wyo. and at Mahogany Ridge, Ida. Previous correlation of beds in the Rex member projected across these areas was substantiated by these sections. A facies change of the upper part of the phosphatic shale from mudstone and phosphorite to chert from Fall Creek, Ida., to Flat Creek, Wyo., was demonstrated by examination and by field correlation of intermediate sections of the phosphatic shale at Teton Pass and Hungry Creek, Ida. A previously unknown horizon of phosphatic sandstone and sandy phosphorite about 25 feet thick was found in the upper part of the Rex member at Mahogany Ridge, a few miles west of Victor, Ida. The presence of phosphate in these rocks was discovered in thin section; these show a range in apatite content of a few percent to about 70 percent (probably equivalent to 5 to 30 percent P_2O_5).

Preliminary petrographic studies show that some phosphorite pellets form diagenetically. A micaceous siltstone, with mica flakes oriented roughly parallel to the bedding, contains pellets of micaceous siltstone cemented by collophane. The mica in the pellets is also oriented roughly parallel to the bedding and some flakes cross pellet boundaries. Thus the cementation by collophane occurred after deposition of the quartz and mica silt. Another specimen of pelletal phosphorite exhibits growth interference of collophane grains giving a mosaic texture. Small pellets appear to have been partially destroyed by the addition of collophane to the larger pellets and others seem to have encircled by secondary collophane to form compound pellets. The extent of diagenetic pellet formation in the Phosphoria formation is unknown although it is certain that, as indicated by broken grains, many phosphorite beds are composed of pellets formed prior to the rocks of which they are a part.

Geology of the Phosphoria and Park City formations in Utah
by T. M. Cheney

Reconnaissance in western Utah and northwestern Nevada during the 1954 field season resulted in the location of two hitherto unreported outcrops--one near Montello, Nev., the other near Kelton, Utah--of rocks equivalent to the Phosphoria and Park City formations. At both localities the section is 3,000 to 4,000 feet thick and is composed dominantly of chert and cherty carbonate rock. At the locality near Kelton a thin phosphatic shale unit was located near the base of the section. A thin phosphatic shale unit was found at the base of the Gerster (?) formation in outcrops in the east Humboldt range, Elko Co., Nev. This is the westernmost locality from which phosphatic shales of Permian age have been reported.

Effects of weathering on phosphate rocks
by L. D. Carswell and V. E. McKelvey

The investigation of the effects of weathering on the composition of phosphate rock continued, with the collection of a suite of about 80 samples from various levels of the Anaconda Copper Mining Company's mine at Conda, Idaho, and the transmittal for analysis of several hundred samples cut by the San Francisco Chemical Company from exploratory workings in the Crawford Mountains. Analyses furnished by both the Anaconda Company and the San Francisco Chemical Company on samples collected from their mines show a steady decrease in phosphate content in high-grade rocks of the lower bed from about 33 percent P_2O_5 near the surface to 30 percent or less a few scores or few hundreds of feet below the surface. Results of a few analyses made by the Survey on the San Francisco Chemical Company's samples from the Crawford Mountains show that as the phosphate content decreases the percent loss on ignition increases in amount that nearly compensates for the decrease in phosphate. This suggests that the chief effect of weathering is leaching of carbonaceous matter and carbonates.

Coatings of a secondary uranium mineral, probably tyuyamunite, were found by the San Francisco Company in its Crawford Mountain workings, showing that some uranium is leached during weathering and redeposited at depth. Uranium analyses on the samples show no indication, however, of any notable enrichment nor of any persistent trend in variations in the uranium content with depth.

Phosphates of southwestern Montana
by W. B. Myers

Field checking in the Willis SW quadrangle and south in the Dell area, by Myers late in June, indicated that the Beaverhead formation includes deposits of post-thrust age. Some of the later deposits underlie post-thrust Tertiary volcanics, some are intercalated, and some overlie the volcanics. Further checking showed that at least two distinctly different ages of basalt flows are associated with the "Beaverhead" deposits. The complexity of these relations has been responsible for failure to recognize the wide variation in age of the deposits referred to the Beaverhead formation.

The post-thrust "Beaverhead" can be distinguished from somewhat similar pre-thrust deposits by field relations and by the general lack of consolidation of the later deposits, as well as by the common presence of many types of volcanic material in the younger rocks.

The presence of volcanic fragments was previously thought to be a reliable criterion for the separation of the later Tertiary basin deposits from the pre-thrust Beaverhead deposits. The study in June, however, disclosed the presence of volcanic material in the Beaverhead itself. Thin andesitic tuff beds and at least one horizon of andesitic cobbles underlain by a thick andesite flow (?) were encountered in pre-thrust deposits of the type section of the Beaverhead formation west of Dell.

The Willis SW field check as well as further photo-interpretation and map study strongly suggest an important amount of late steep fault movement involving the post-thrust "Beaverhead" and Tertiary volcanics, both in the Willis SW and NW quadrangles. These faults had previously been overlooked or were thought to have been active at an earlier period exclusively. Map relations in the Willis NW quadrangle suggest that at least the earlier of two stages of glacial deposits have been displaced by Recent faulting.

Southeast phosphate

Exploration
by W. L. Emerick

Company drilling

The following drilling on land to be mined prior to 1965 was carried out by phosphate companies, on their own property, under contract with the AEC:

	Holes drilled		Footage		Contract
	Last report	Total to date	Last report	Total to date	percent completed
American Cyanamid Company	93	139	3,293.0	4,588.0	100
Davison Chemical Company	0	26	0	982.6	100

Samples from the aluminum phosphate and calcium phosphate zones were collected from drill holes by the companies for analyses of U, P_2O_5, Al_2O_3, and CaO. The gamma-ray logging unit of the Geological Survey logged all of the holes on the AEC contracts with the companies.

Mobile drilling

A mobile drill was used intermittently during August and September for exploratory drilling to delimit zones of aluminum phosphate. The drilling was recessed for an indefinite period in September.

Radioactivity logging of drill holes

A total of 184 holes aggregating 6,128 feet were logged by the gamma-ray unit. The cumulative total for the gamma-ray unit is 3,473 holes totalling 123,404 feet.

Economic geology of the land-pebble phosphate deposits
by J. B. Cathcart

Most of reporting period was spent in compiling data and writing reports on the economic geology of the aluminum phosphate zone on lands owned by each of the companies active in the field. The series of reports should be finished by the end of the calendar year 1954. Although the work is incomplete, it is possible to make certain generalizations regarding the distribution of the aluminum phosphate zone and of the uranium in the zone.

The zone is thickest and most persistent in the flatwoods area and on the flanks of the ridge area, whereas in the ridge area itself it is thin, discontinuous, or absent. It is not present in economic amounts in the valley zone (see fig. 46). The outline of the ridge area on figure 46 is the 140-foot contour line, and the east flank of the ridge, toward the Peace River, is underlain by possibly economic material. Conversely, the west side in the flatwoods area, particularly in Tps. 30 and 31 S., R. 23 E., is underlain only in part by economic aluminum phosphate zone.

Vertical variation in uranium content in the zone, shown by gamma-ray logs (fig. 47), seems to follow several patterns:

(1) Two or more high peaks separated by a barren zone. Overburden is generally thick, with loose sand at the top, followed by slightly clayey sand that is higher in radioactivity than the loose sand, but is questionably economic. This condition is characteristic of the central ridge area.

(2) A high peak at the top of the zone, just below the contact with the barren quartz sands of the overburden. The uranium content decreases with depth until it reaches a level equal to the radioactivity of the matrix. This is characteristic of the east flank of the ridge and part of the flatwoods.

(3) Uranium content low at the top of the zone, and the upper part of the zone questionably economic. Radioactivity rises to a peak at the base of the zone, at or near the contact with the underlying matrix. This is characteristic of the flatwoods area. A variation of this profile has a broad high peak close to the center of the zone, with the top and bottom of the zone lower in radioactivity.

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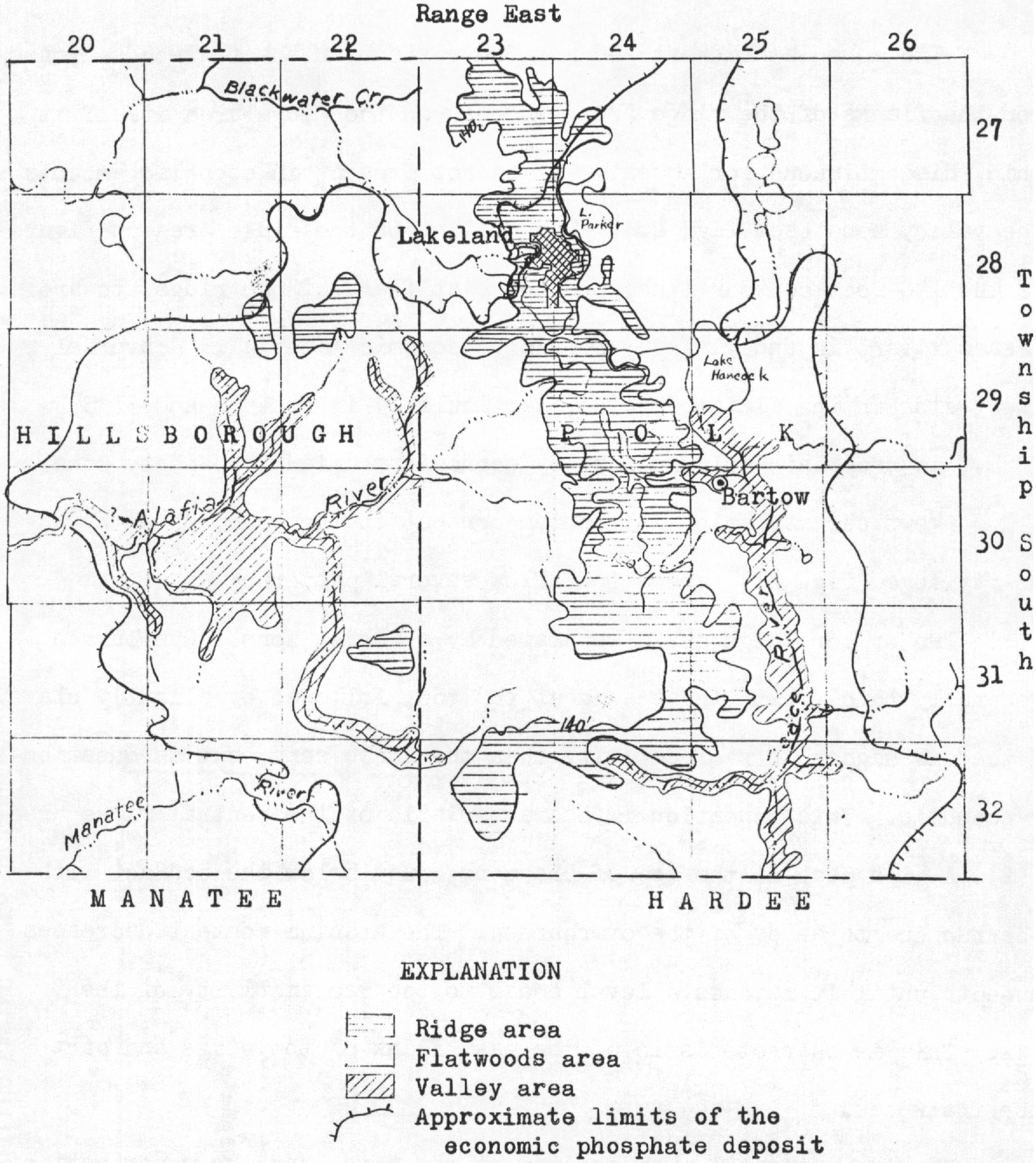

FIG. 46. INDEX MAP, LAND-PEBBLE PHOSPHATE DISTRICT, FLORIDA,

SHOWING PHYSIOGRAPHIC DIVISION.

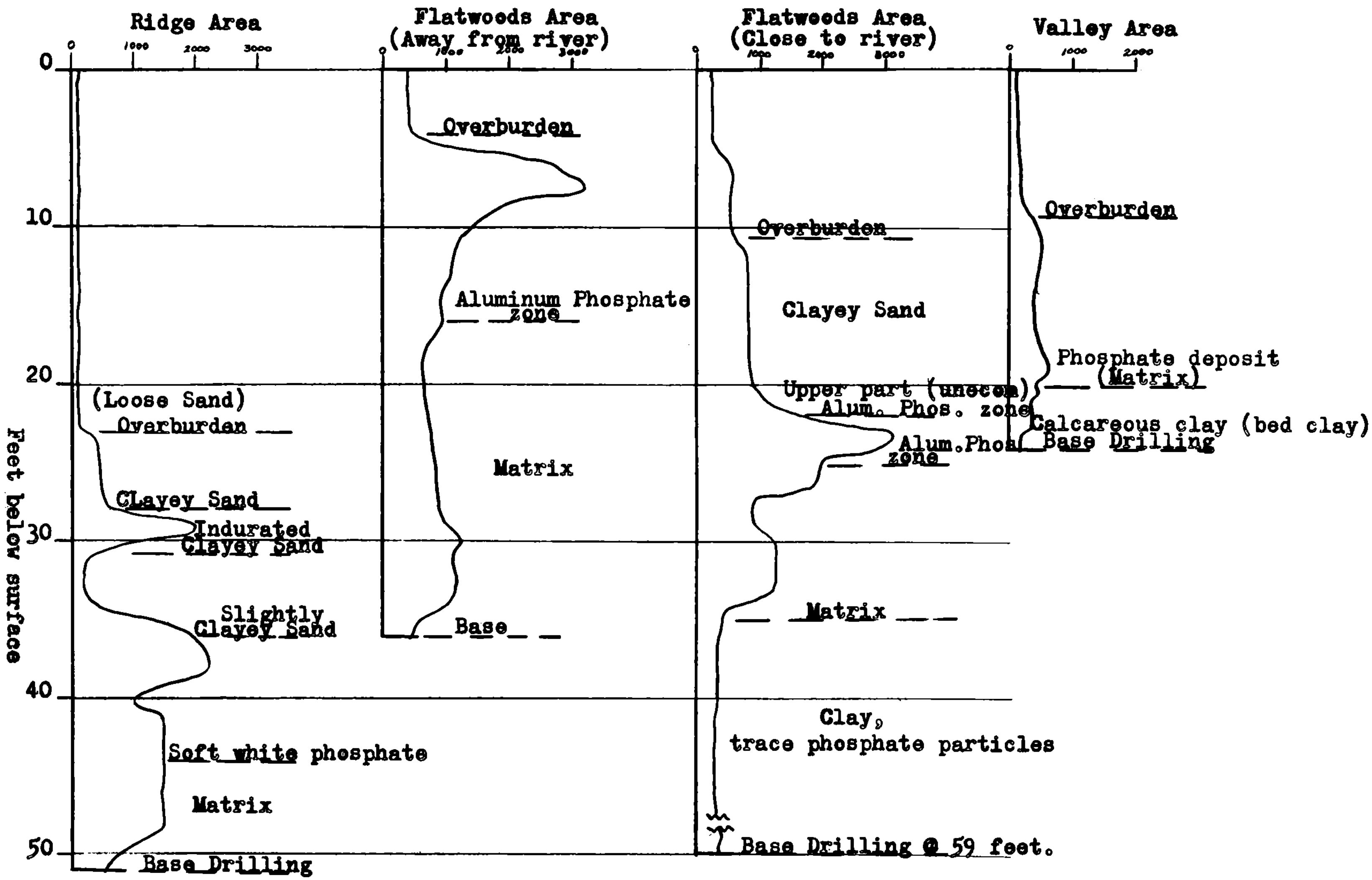

Fig. 47 DIAGRAM ILLUSTRATING TYPES OF GAMMA-RAY LOGS, LAND-PEBBLE PHOSPHATE DISTRICT, FLORIDA

(4) No zone present, and uranium content of the matrix much lower than in the ridge or flatwoods areas. Characteristic of the valley area.

Geologic study of phosphate deposits and their "leached zones" in the northern half of Florida
by G. H. Espenshade

A geologic study of the phosphate deposits and phosphatic sediments in Florida outside of the land-pebble phosphate district was begun in July 1954. The objectives are to investigate the nature, extent, and origin of the deposits, and to obtain information on the distribution of uranium in these deposits and their so-called "leached zones" or aluminum phosphate zones. The following discussion, and previous studies of the occurrence of uranium in them, outlines the nature and scope of the problem.

Distribution and nature of deposits

The deposits are distributed throughout an area of several thousand square miles in the northern half of the Florida peninsula and appear to be of several geologic types (Mansfield, 1942, USGS Bull. 934). The best known type is the hardrock phosphate deposits, which occur near the western side of the peninsula in a narrow northwest-trending belt more than 100 miles long. They are irregular discontinuous bodies that generally have been thought to be of replacement origin. They are overlain by an extensive cover of phosphate-cemented sand, which has some similarities to the "leached zone" overlying the matrix in the land-pebble district. The phosphate-cemented sand appears to be more widely distributed than the hardrock deposits. The other phosphate deposits to the east, north, and northwest of the hardrock belt are not so well known; the principal types are land-pebble and river-pebble deposits, phosphatic sediments of the Hawthorn formation, and the highly weathered residuum of phosphatic sediments.

Previous studies

A preliminary investigation of the distribution of uranium in the phosphate-cemented sand of the hardrock belt was made by Ketner (TEM-168, 1954). Phosphate deposits in the southern half of the hardrock belt have been prospected by the Tennessee Valley Authority during the past 4 years. Some of the phosphate deposits to the east and north of the hardrock belt have been covered by airborne radioactivity surveys of the USGS (Moxham, 1954, USGS Circular 230). Several of the anomalies discovered by these surveys were drilled and sampled recently (Cathcart, 1954, USGS open-file report).

Current work

The current geologic study of these deposits is mainly reconnaissance in nature because of the large area involved. Representative areas and deposits will be investigated in some detail, however, by physiographic, stratigraphic, and petrographic studies. A mobile auger drill is being used to obtain samples and to gather stratigraphic data. More precise methods of sampling by means of drilling may be used later if necessary.

Field work began in October. Work so far has consisted mainly of getting acquainted with the hardrock phosphate belt and of experimenting with the operation of the mobile drill. Data on the extent, thickness, and uranium content of the phosphate-cemented sands in the hardrock phosphate belt will be gathered from phosphate pits and auger drill holes along several east-west sections taken at appropriate intervals across the northwest-trending belt. This information will be supplemented by TVA drilling records where they are available. It is hoped that this work also will reveal clues to the geologic features that controlled the localization of the phosphate deposits.

Occurrence of uranium in phosphate deposits
by Z. S. Altschuler, R. S. Clarke, Jr., and E. J. Young

Geochemistry

The most reliable analyses for U^{+4} in apatite have been obtained by a modified cupferron precipitation method. Recent work by AEC contractors indicates that cupferron enhances the reduction of U^{+6} by ferrous iron. This raises the question of whether U^{+4} values obtained from natural apatites are the result of reduction during the course of analysis, particularly as requisite amounts of ferrous iron are present in the sedimentary apatites tested. Accordingly, to test the validity of the previously obtained U^{+4} data synthetic fluorapatite was spiked with 0.12 percent of Fe^{+2} and 0.015 percent of U^{+6} (approximately the percentages of total iron and total uranium found in previously run sedimentary apatite) and the mixture was analysed for U^{+4} by the cupferron method. Only 0.0003 percent of U^{+4} was recovered, proving that the appreciable percentages of U^{+4} obtained from natural materials are inherent to the samples rather than the analytical procedures. Thus, in natural samples more than 50 percent of the uranium shows up as U^{+4}, whereas in the above experiment only 2 percent of the original uranium was reduced by the analytical procedure.

Field studies

The relations between topography and the deposition of the upper Bone Valley formation and its mantle of loose quartz sands were studied by making mechanical analyses of sands and plotting the results on a topographic map. A definite relation was found to exist between the distribution of median diameters and first and third quartile values and the regional topography of the Land Pebble field. Isograde maps of each of the above parameters were found to conform to the topographic contour map of the district. These relations can serve as a basis for discussion of the influence of regional structure on the depositional history of the Bone Valley formation.

Petrology

Samples of apatite of unusually high uranium content were studied by autoradiographic and nuclear emulsion methods to obtain knowledge of the distribution of uranium within them. One specimen, consisting of apatite cement in an arkose, had 0.74 percent U; another, a fossil bone from South Dakota, had 0.083 percent U. In both specimens the uranium was found to be uniformly distributed on a microscopic scale and not localized or concentrated in inclusions. Concentration of uranium occurred only on a macroscopic scale, peripheral areas of the bone being much richer than internal areas. It is interesting to note that uranium in these highly enriched materials occurs in the same manner that it does in normal sedimentary apatite of much lower grade (0.01-0.02 percent U), revealing that the lower grade apatites are far from saturated with uranium.

In study of well cuttings from the Clark-James tract, in the Land Pebble Field of Florida, it was found that the uraniferous material is iron stained and impregnated apatite. Although this area may have been secondarily altered and enriched in uranium, it is not analogous to the aluminum phosphate zone of the Peace River basin, as it lacks the secondary aluminum- and calcium-aluminum phosphates. In addition, an appreciable part of the uranium in the Clark-James tract is associated with goethite and limonite. This is revealed by analyses of magnetic and specific gravity splits in which it was found that uranium paralleled iron more closely than it did phosphorus or calcium.

URANIUM IN PLACER DEPOSITS

Central Idaho placers
by D. L. Schmidt

Uranothorite placers in the Camp Creek-Rock Creek area, Hailey, Idaho

The Camp Creek-Rock Creek area is in south-central Idaho, 10 to 15 miles southwest of Hailey. Uranothorite-bearing gravel deposits were drilled by the U. S. Bureau of Mines in 1954 to determine the grade and yardage available for mining. The purpose of the geologic study outlined here is to investigate the origin of the uranothorite and of the placer deposits. The field work consisted of: (1) investigation of the distribution of uranothorite in the bedrock, (2) mapping of the extent of the various gravel deposits, (3) mapping of the Tertiary and Quaternary volcanic rocks in search of possible interbedded placer gravels, and (4) reconnaissance investigation of radioactive gold-quartz veins in the granitic rock. Approximately 500 pan samples of bedrock, soil, and gravel were evaluated for radioactivity, but quantitative mineralogical study has been completed on only about one quarter of the samples.

Geologically the Camp Creek-Rock Creek area is in the southeastern border zone of the Idaho batholith. The batholith consists locally of a younger quartz monzonite and an older diorite, both intrusive into the Wood River formation of Pennsylvanian age. The granitic rock and the Wood River formation are overlain unconformably by a sequence of Tertiary and Quaternary volcanic rocks.

It is evident from their distribution that the placers were formed by streams heading in the granitic rock, and that the accumulation of placer deposits was in part controlled by blocking of the drainage lines by flows of Snake River basalt.

The uranothorite occurs as an accessory mineral disseminated in the quartz monzonite. Thorough examination indicates that little or no uranothorite occurs in pegmatite, aplite, or alaskite bodies which occur with the quartz monzonite and that no uranothorite occurs in lamprophyre dike rocks, older diorite, Carboniferous rocks, nor in any of the younger volcanic sequence. As there is no visible difference between uranothorite-bearing and uranothorite-free quartz monzonite, the distribution of the uranothorite must be determined by panning methods.

Camp Creek drains the portion of the quartz monzonite containing the largest amount of uranothorite per unit of area. The richer Camp Creek placer deposits are of two types: old dissected bench gravels, and recent (?) flood-plain gravels. The bench deposit is an aggradational fill caused by blocking of Camp Creek by a basalt flow in middle Pleistocene time. The recent (?) Camp Creek flood-plain deposit is richer than the bench deposit because it is receiving uranothorite from the bedrock and additional heavy sands from dissection of the earlier bench deposits. The Rock Creek and Poverty Flat placer deposits are lower in grade than those of Camp Creek, reflecting the difference in uranothorite content in the drainage basins of these streams. Some of the large gravel areas downstream from the Camp Creek placer deposits are also of lower grade because of dilution by adjacent streams.

Stream gravel deposits occur in valleys buried beneath the Tertiary and Quaternary volcanic units, but none of these gravels contains sufficient uranothorite to be of economic significance.

Gold-quartz veins of the Hailey gold belt, within the zone of uranothorite-bearing quartz monzonite, locally show anomalous radioactivity. The veins do not contain uranothorite and have contributed nothing to the stream placers. The principal uranium-bearing mineral (perhaps uraninite), is almost wholly destroyed by surface weathering. Surface samples contain torbernite and other secondary uranium minerals. The samples contain too little uranium to be of minable grade, but may not be representative of the grade at depth because of downward leaching of uranium.

RECONNAISSANCE FOR URANIUM IN THE UNITED STATES

Northeast district
by Harry Klemic

Approximately $3\frac{1}{2}$ months of this report period were spent in the field. Regular field work was recessed September 3, but several brief field investigations were made during September, October, and November. Most of the time in the office was spent in compilation of field data, in laboratory studies of samples, and in preparation of reports.

Phillips mine area, Putnam and Westchester Counties, N. Y.

The geology of an area about 4,500 feet by 1,800 feet in the vicinity of the Phillips mine was mapped on a scale of 1:2,400. A dip-needle magnetic survey and a scintillation-counter radioactivity survey of the area indicated a close, but not constant, spatial relationship between magnetic anomalies and radioactivity anomalies. Uraninite occurs in a mafic pegmatite and in hornblende gneiss near the pegmatite-gneiss contacts.

Pennsylvania

Geologic mapping and detailed radioactivity reconnaissance were done in the vicinity of the uranium occurrences in Carbon County. The mapping showed that all known occurrences in the Catskill formation of Devonian age are at approximately the same stratigraphic position. Water samples were taken from ten streams that drain the Pocono Plateau near Jim Thorpe. An airborne survey was made over an area of approximately 320 square miles in Carbon and Monroe Counties. No new occurrences of uranium or significant radioactivity anomalies were discovered.

Prospectors discovered four occurrences of uranium in Devonian rocks in Fulton and Huntingdon Counties, and one in Dauphin County. Uranium was found in Mississippian rocks in Luzerne County and in Triassic rocks in Bucks County. The occurrence in Bucks County has not been examined. All of the other occurrences are small and spotty, but are of interest because they are the first reported occurrences of uranium in these counties.

New Jersey

A zircon crystal from the Scrub Oaks mine in Morris County was determined by the Larsen method to be about 525 million years old. The zircon occurs as coarse dark-brown crystals in a coarse-grained rock composed of milky quartz, magnetite, zircon, and a mineral rich in yttrium. The yttrium mineral is believed to be a new species.

Maine

Two radioactivity anomalies, in Aroostook County near the DeBoullie Mountains and near Eagle Lake, were discovered by airborne methods. The source of these anomalies has not been determined.

North-central district

by R. C. Vickers

Northern Black Hills, South Dakota

Belle Fourche area

Detailed geologic mapping of about 3 square miles surrounding the Kling-Bonado uranium occurrences, secs. 23, 24, 25, and 26, T. 8 N., R. 1 E., Butte Co., S. Dak., has shown that all the known uranium occurrences are near the horizontal change from pink or red sandstone to gray or buff sandstone within the lower unit of the Fall River formation. A scintillation-counter survey along the contact between pink and buff sandstone located four previously unknown carnotite deposits and numerous radioactivity anomalies. Ground reconnaissance northwest of the mapped area showed additional radioactivity anomalies along the strike of the color change in the sandstone. Southwest of the mapped area the contact between pink and buff sandstone was not observed in outcrop and is presumed to be down dip.

Detailed mapping of the structure in the area (structural contours at 5-foot intervals) shows that in detail the pink to buff contact cuts across the minor structures but in general parallels the regional strike of the beds. Some of the carnotite deposits appear to be localized at the pink-buff contact where there is favorable structure, such as local flattening or reversal of the dip and local upward flexures. Because the carnotite occurrences seem related to local structural features, and because of the small size of the known ore bodies (less than 500 tons), the possibility of finding larger ore bodies seems remote.

It is noteworthy that, in the mapped area, abnormal radioactivity was detected at almost all exposed contacts between pink and buff sandstone of the lower unit of the Fall River formation. This suggests that uranium mineralization probably occurred along the sinuous contact everywhere in the mapped area, a total distance of about 5 miles, and may extend for a considerable distance outside the area.

Lamberton uranium occurrence

During July, a detailed geologic study was made of part of the Lamberton property, sec. 30, T. 5 N., R. 6 E., Meade Co., S. Dak. Anomalous radioactivity over a large area (about 1800 feet long and from 900 to 1800 feet wide) is caused mainly by residual boulders and large blocks of Fall River sandstone partly covering a dip-slope surface of a hogback. In contrast to the unmineralized friable light-buff fine-grained Fall River sandstone, the radioactive rocks at this locality is a well-cemented medium-grained dark-gray rock containing carbonate and is partly silicified on weathered surfaces. Uranium analyses are estimated to range from 0.02 to 0.08 percent.

Owing to the lack of outcrops, the limit of the occurrence down dip from the residual boulders is not known.

Because of the large tonnage of radioactive material present--possibly more than 50,000 tons--and because of the low costs in mining the residual rock, the occurrence may have economic significance.

The area is of interest because it is on the northeast flank of the Black Hills uplift where no uranium has been previously reported. A smaller similar radioactive occurrence in the lower sandstone of the Lakota formation is about 3 miles to the northwest.

Bear Butte

Small areas of abnormal radioactivity are near the base of the Sundance formation about 1 mile west of Bear Butte in secs. 13 and 24, T. 6 N., R. 5 E., and adjacent secs. 18 and 19, T. 6 N., R. 6 E. Abnormal radioactivity is present in both fine-grained sandstone and in impure silicified (?) limestone. Some of the samples contain about 0.03 percent eU.

Although these occurrences of uranium are not of economic importance, they extend the stratigraphic limits of uranium mineralization in the northern Black Hills and suggest that under suitable conditions the

Sundance formation might be a suitable host rock for uranium elsewhere. Geologic mapping and a scintillation-counter survey show that the radioactivity anomalies are distributed around the flanks of a structural dome about 1 mile in diameter and that this structural feature may have localized the uranium deposition.

Bald Mountain mining area

Abnormal radioactivity on the Revenue Claim, near the center of sec. 1, T. 4 N., R. 2 E., Lawrence Co., S. Dak., was found by geologists of the Bald Mountain Mining Company. The radioactive material, exposed in one small prospect pit, consists of altered Deadwood formation of Cambrian age containing limonite and secondary manganese minerals. A grab sample contained more than 0.5 percent eU, but much of the radioactivity may be caused by thorium. The prospect pit is only a few hundred feet from an area of radioactive material in an adit on the Dark Horse (?) claim, described in USGS Circular 351 (1954). Both occurrences may be along the same set of mineralized fractures and have similar mineral assemblages, including rare-earth minerals.

Michigan

Greens Creek

A shallow trench dug across an area of abnormal radioactivity near Greens Creek, sec. 19, T. 46 N., R. 26 W., Marquette Co., disclosed the presence of meta-torbernite (?) which occurs as disseminations in interbedded carbonaceous slate and quartzite of upper Huronian (?) age. The radioactive zone is about 8 feet wide where exposed by the trench, and abnormal radioactivity is detectable for about 30 feet along the strike of the slate and quartzite. Most of the meta-torbernite is in a zone about 1 foot wide; selected samples contain as much as 0.4 percent eU. No minerals suggestive of a hydrothermal source for the uranium were observed. In addition to meta-torbernite, much of the uranium appears concentrated in carbonaceous pellets and thin seams.

Gwinn district

Radioactive iron ore was found by scanning drill core from the Gwinn district, Marquette Co. Two 3-inch specimens from an underground drill hole in an abandoned mine contain 0.24 and 0.068 percent eU and 0.12 and 0.08 percent U, respectively. As only a small percentage of the core was available, the specific subsurface location and thickness is not known.

South-central district
by E. P. Beroni

Reconnaissance in Missouri, Arkansas, Louisiana, Texas, and Oklahoma disclosed 15 uranium-bearing localities not previously reported (fig. 48). In addition, new occurrences were found in seven previously reported areas.

Oklahoma

Permian Red-Bed deposits, southwestern Oklahoma A

The most promising known uranium-bearing localities in Oklahoma are in the Permian Red Beds in Tillman, Cotton, and Jefferson Counties, south of the Wichita Mountains. Limited private exploration on a deposit in sec. 30, T. 5 S., R. 12 W., southwest of Randlett, Cotton Co., showed the deposit to be in a sandstone lens approximately 300 feet wide, 25 feet

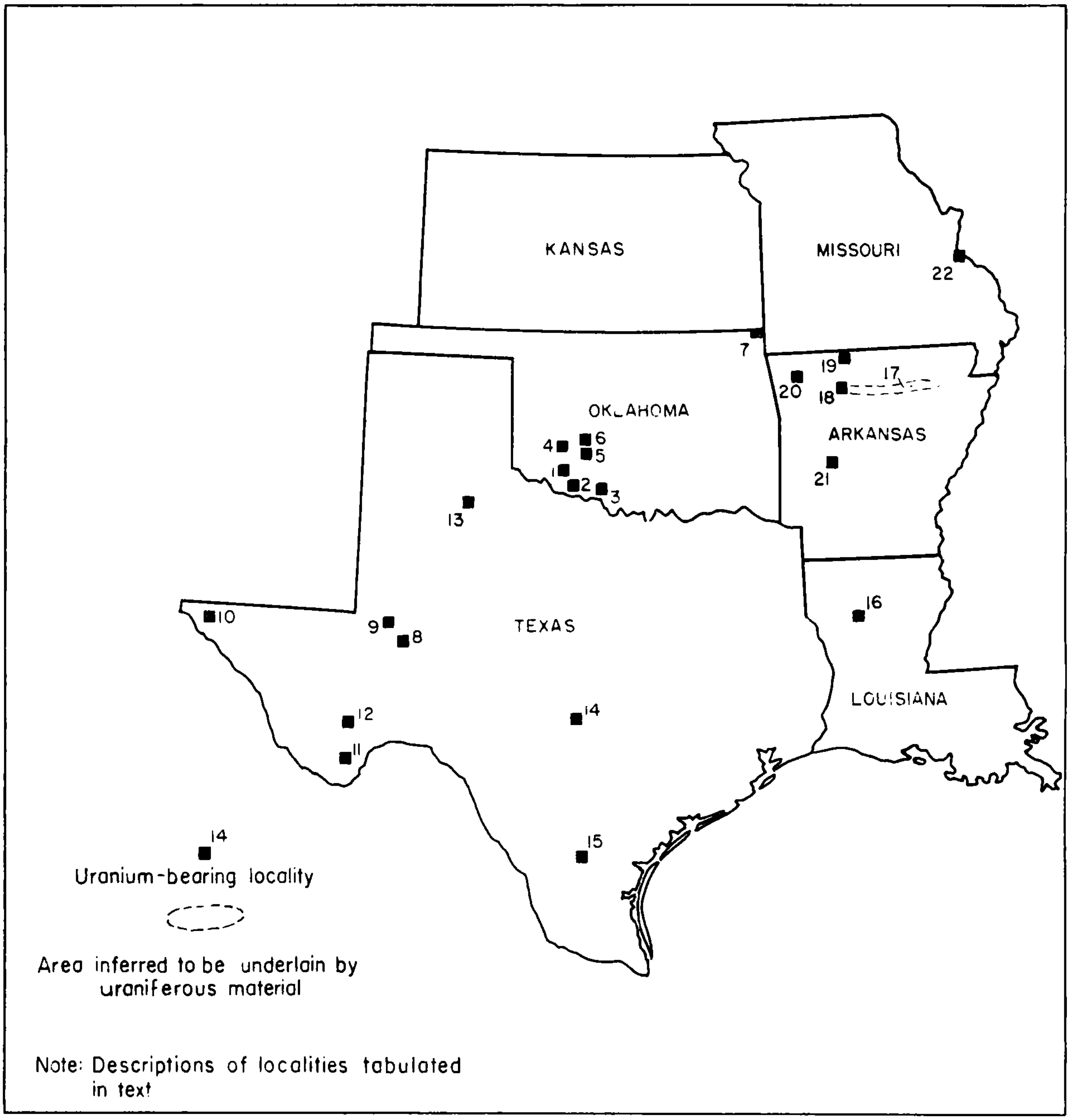

FIGURE 48 -INDEX MAP OF SOUTH-CENTRAL DISTRICT, SHOWING NEWLY DISCOVERED URANIUM-BEARING LOCALITIES

thick and 600 feet long which trends approximately N. 20 E. The lens projects into the underlying sandy shales to a depth of approximately 10 feet. Bulldozing of the cliff face revealed a uranium-bearing zone 25 feet long and 2 to 4 feet thick. The lower 10 feet of the lens contains the mineralized zone, which is characterized by torbernite, autunite, uranophane, carnotite, and bayleyite (?) associated chiefly with malachite and azurite in heavily iron- and manganese-stained rock. Small amounts of uraninite also are associated with copper sulfide minerals replacing woody fragments. Analyses of samples indicate a uranium content ranging from 0.04 to over 1 percent.

According to G. W. Chase (Oklahoma Geol. Survey Mineral Report 26, 1954), the most favorable horizon for uranium in Southwest Oklahoma is the Garber formation of Permian age. Figure 49, which is based on a map in Chase's report, shows the distribution of the Garber formation as well as other formations in the vicinity of the uranium-bearing localities of southwest Oklahoma. Equivalent copper-bearing Permian Red Beds are present in the Vernon-Wichita Falls area of northern Texas; these also may be favorable for the occurrence of uranium.

Limited private trenching in sec. 1, T. 1 S., R. 15 W., 9.5 miles east of Manitou, Tillman Co., showed uranium-bearing material in an "arkosic sandstone" of the Permian Red Beds, 5 to 10 feet thick, which is heavily stained with iron, manganese, and asphalt. Selected samples from this area contain as much as 0.3 percent uranium. Analyses of channel samples indicate a uranium content from 0.06 to 0.11 percent.

It may be significant that the majority of the uranium deposits in southwest Oklahoma are on or near the flanks of a large anticline from which a large amount of helium gas was produced in the Petrolia, Texas, field.

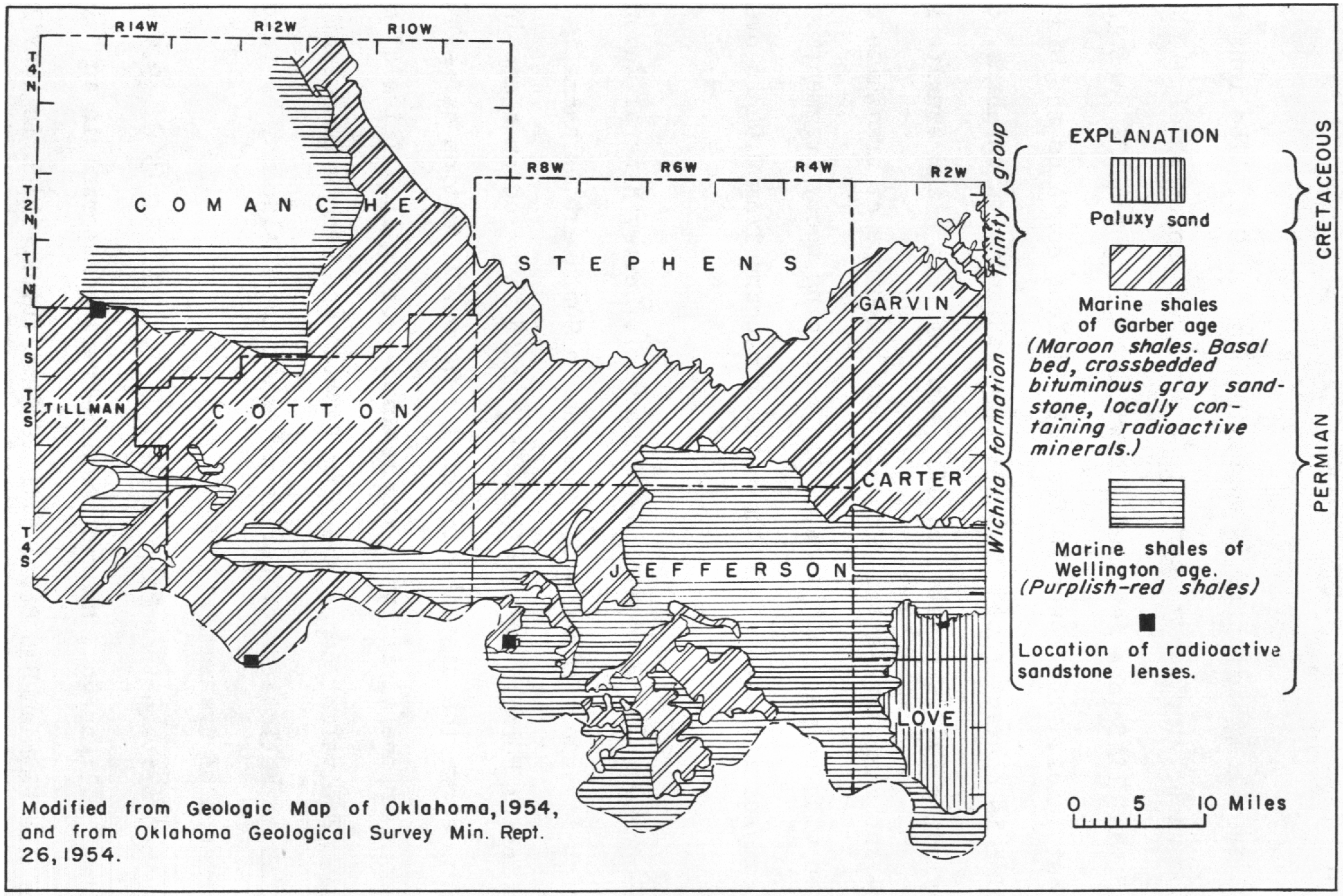

FIGURE 49 -GEOLOGIC MAP OF A PORTION OF SOUTHWESTERN OKLAHOMA, SHOWING THE APPROXIMATE OUTCROP OF THE BED LOCALLY CONTAINING RADIOACTIVE MATERIAL.

Texas

Permian deposits, Trans-Pecos region

In the Trans-Pecos region, carnotite and tyuyamunite have been found on bedding planes and coating fractures in the Hueco limestone of Permian age. All the deposits are approximately within the same horizon in the dolomitic limestone. Preliminary reconnaissance shows that playa lake beds near the deposits are appreciably radioactive. Many carnotite and tyuyamunite localities currently are being discovered in or near areas characterized by major fault zones within the Hueco Mountains. These deposits are near Tertiary intrusive and extrusive rocks. The geology of this area has been described in USGS Oil and gas investigations map 36, "Geology of the Hueco Mountains, El Paso and Hudspeth Counties, Texas," by P. B. King, R. E. King, and J. B. Knight, 1945.

Analyses of selected samples from this area indicate an equivalent uranium content from 0.014 to 0.20 percent. The uranium content of the samples ranges from 0.018 to 0.20 percent. Additional information concerning the deposits in the Heuco Mountains is given in "Sedimentary rocks of Texas" in this report.(p. 164).

Arkansas

Ozark Dome region

In the Ozark Dome region of northern Arkansas, the Pitkin limestone of Mississippian age and the Atoka formation of Pennsylvania age contain appreciable uranium-bearing asphaltic material. The geologic setting of the asphaltic material is not completely understood. Some samples from the black marble quarries in northern Arkansas contain up to 0.075 percent uranium in the oil ash. Fresh pellets extracted from the asphaltic Pitkin limestone contain up to 0.5 percent uranium.

There are numerous black marble quarries in northern Arkansas in Searcy, Stone, Cleburne, and Independence Counties. The black marble beds crop out south of the White River in a narrow belt commonly less than 10 miles wide, which extends along the north slope of the Boston Mountains escarpment for approximately 70 miles from T. 12 N., R. 5 W., to a few miles south of Marshall, in T. 14 N., R. 16 W. (See locality 17 on fig. 48). Additional asphaltic sandstones crop out in Newton, Madison, and Washington Counties.

Northwest district

by F. L. Weis

During the past six months, more than 350 callers with questions on uranium were interviewed, more than 300 letters answered, and more than 200 samples tested for radioactivity. Of the samples tested, specimens from 16 localities showed equivalent uranium content equal to or greater than the minimum required for commercial ore. Six of the localities have been examined, and work on several others is contemplated. Some samples came from localities that are now inaccessible or where the discoverer has not yet obtained control of the property.

Two important new uranium deposits have been discovered. One is the Surprise claims, near Gibbonsville, Lemhi Co., Idaho. The claims are on a quartz vein that strikes N. 60 W. and dips steeply to the northeast. The vein has been traced for more than 1,400 feet along strike. It ranges from 10 to more than 40 feet in thickness, and is radioactive along a horizontal distance of at least 1,200 feet. The most intense radioactivity appears confined to the footwall. Autunite and metatorbernite have been recognized, and several samples collected from bulldozer trenches assayed well above the minimum commercial grade. The deposit is of particular interest because it lies only about 3½ miles from the Garm-Lamoreaux mine, where pitchblende and zippeite have been recognized in dump material. The possibility of additional discoveries in the area appears favorable, and further reconnaissance will be done.

The second deposit was discovered near Wellpinit, Stevens County, Washington, where autunite occurs as fracture fillings and impregnations along and on both sides of the contact between the Loon Lake granite and the Deer Trail argillite. Anomalous radioactivity has been detected for more than a mile along the contact. The owners expect to begin shipping ore within a few months. The possibility of other deposits along the granite-argillite contact will be investigated.

New Mexico and southeastern Colorado

by E. H. Baltz, Jr.

Carbonaceous shale of the Magdalena group of Pennsylvanian age and carbonaceous beds in the Sangre de Cristo formation of Pennsylvanian-Permian age were examined in parts of Taos, Colfax, Mora, and San Miguel Counties, northeastern New Mexico. Only traces of radioactivity were detected.

Radioactivity estimated to be as much as 0.01 percent eU was detected in carbonized plant remains in stream channel deposits of the Chinle formation of Triassic age near the settlements of La Liendre and Trujillo in San Miguel County. No concentrations of radioactive material of probable economic importance were discovered in this area. However, uranium deposits of possible economic value have been discovered in the Chinle formation near

Sabinoso in eastern San Miguel County. Selected specimens of arkosic sandstone from a prospect in sec. 29 (?), T. 17 N., R. 24 E., contain 1.0 to 2.78 percent uranium. A 3.2-foot channel sample contains 0.22 percent uranium. High radioactivity was detected for a radius of at least 150 feet from the prospect. Several more recent discoveries are in secs. 1, 23, and 24, T. 17 N., R. 24 E., and in secs. 18 and 19, T. 17 N., R. 25 E. A prospect in sec. 24, T. 17 N., R. 24 E., disclosed a bed of limestone pebble conglomerate 2½ to 4 feet thick containing an estimated 0.1 percent eU. Selected specimens of carbonized logs from this zone contain as much as 0.5 percent uranium. Eighteen holes have been drilled near this prospect but information on results of the drilling is not available.

Igneous sills of intermediate composition were examined in the Chinco Hills, Colfax County, New Mexico. Small amounts of radioactive material, estimated to be as much as 0.007 percent eU, are present over wide areas in the intrusive rocks, but no anomalous radioactivity was detected in the enclosing shales of the Colorado group of Cretaceous age.

Anomalous radioactivity was detected in beds of the Permian Cutler formation in the northeastern part of the Jemez Plateau, Rio Arriba County, north-central New Mexico. At least six prospect pits have been opened in copper-bearing arkosic sandstone and shale in T. 21 N., R 2 E. A representative sample of copper-bearing arkosic sandstone collected from a prospect in NW¼ sec. 23, T. 21 N., R. 2 E., contains 0.011 percent uranium. A similar sample of sandstone collected from a prospect in NE¼ sec. 34, T. 21 N., R. 2 E., contains 0.004 percent uranium. A 2-foot channel sample of conglomeratic, highly carbonaceous arkosic sandstone collected in NE¼ sec. 14, T. 21 N., R. 2 E., contains 0.050 percent uranium. Beds containing highly radioactive material at this prospect are at least 5 feet 3 inches thick, and radioactivity was detected on the surface in an area of about 1½ acres. Abnormally high background radioactivity was detected in Pleistocene Bandelier tuff which is present about one-quarter of a mile east of the prospect. Two samples of highly ferruginous sandy clay shale collected from a prospect in the NE¼ sec. 8, T. 22 N., R. 3 E., contain 0.095 and 0.10 percent uranium. These samples were collected from two lenses each about 2½ inches thick and 3 feet long which are enclosed in a massive arkosic sandstone of the Cutler formation.

A 3-foot bed of impure coal exposed on the north side of Cerro Blanco Canyon in sec. 4, T. 23 N., R. 1 E., contains an estimated 0.05 percent eU. A black shale bed 2 feet thick cropping out in a small canyon in sec. 27, T. 24 N., R. 1 E., contains an estimated 0.007 percent eU.

Traces of radioactivity were detected in sediments of the Mesaverde formation at two localities in Archuleta County, Colorado, and northern Rio Arriba County, New Mexico. Thin beds of carbonaceous and coaly shale near the middle of the Mesaverde formation north of Amargo Arroyo (NW¼, sec. 15, T. 31 N., R. 1 E.) in Rio Arriba County, New Mexico, contain an estimated 0.004 percent eU. Thin beds of carbonaceous shale in the middle of the Mesaverde formation on the west side of the Navajo River (NE¼, sec. 6, T. 32 N., R. 1 E.) in southeastern Archuleta County, Colorado, contain an estimated 0.004 percent eU.

Permian and Quaternary sedimentary rocks and Tertiary intrusive rocks were examined in Lincoln and Otero Counties, central New Mexico. Radioactivity three or four times background count was detected in granite wash at the base of the Permian Abo formation in sec. 36, T. 13 S., R. 10 E., in the Sacramento Mountains, Otero County. Abondoned workings of the Virginia mine in sec. 25, T. 13 S., R. 10 E., were examined but only traces of radioactivity were detected in copper-bearing Abo sandstone and in a dike of diorite porphyry exposed in the mine. Radioactivity two times background count was detected in Quaternary peat beds in the valley of Spring Creek in sec. 29, T. 15 S., R. 13 E., in the Sacramento Mountains.

A brief reconnaissance examination was conducted in the Huerfano Park region of southeastern Colorado. Uranium has been recently discovered near Cuchara Camp, Huerfano County in sec. 33 (?), T. 30 S., R. 69 W., in copper-bearing sandstone of the Sangre de Cristo formation. Selected specimens from a tunnel on the prospect may contain more than 1.0 percent uranium. Extent of the deposit has not been determined. Radioactivity estimated to be 0.008 percent eU was detected in a thin bituminous limestone of the Wanakah formation in a road cut in the NW$\frac{1}{4}$, sec. 35, T. 30 S., R. 69 W.

Radioactivity estimated to be about 0.005 percent eU was detected in acidic volcanic tuff of Tertiary age in sec. 21, T. 24 S., R. 70 W., Huerfano County, Colorado. The beds of tuff may be more than 1,000 feet thick and overlap the truncated edges of older sedimentary rocks on the west flank of the Wet Mountains in Huerfano County. Carbonaceous rocks of the Dakota formation, Graneros shale, Greenhorn limestone, Carlile shale, Niobrara formation, and Pierre shale are overlapped by these tuffaceous beds in the west part of T. 25 S., R. 70 W.

Colorado-Wyoming district

by P. K. Theobald and R. U. King

Colorado

Colorado Front Range

Eight abnormally radioactive areas in Boulder, Jefferson, and Gilpin Counties were examined during the report period. Reconnaissance mapping is in progress at the F.M.D. mine. The localities are briefly described below.

Diamond Lake.--Near Diamond Lake in sec. 2, T. 1 S., R. 74 W., high radioactivity is associated with pegmatite, coarse biotite-enriched zones, shear zones, and hornblende gneiss along the contact of the Boulder Creek granite with the Idaho Springs formation. At one place visible secondary uranium minerals are mixed with coarse biotite in pegmatite. A sample of pegmatite contains 0.035 percent U; a sample of granite gneiss contains 0.21 percent U.

F.M.D. mine.--At the F.M.D. mine, sec. 25, T. 4 S., R. 71 W., a group of prospects are along a mineralized zone that trends N. 50° to 65° W., parallel to metamorphic banding. Iron, copper, and zinc minerals are visible in this zone which follows the contact of biotite granite gneiss with hornblende gneiss. An increase in radioactivity in the granite gneiss (0.025 mr/hr) over that in the hornblende gneiss (0.01-0.02 mr/hr) is accentuated by abnormally high radioactivity along the mineralized zone (0.04-1. mr/hr).

Idledale.--A radioactive deposit in sec. 32, T. 4 S., R. 70 W., on the north side of Bear Creek Canyon, half a mile west of Idledale, is being prospected. A breccia reef trends N. 50° W. across the crest of a spur. Hornblende gneiss that trends N. 50° to 60° W. is radioactive where cut by north-trending fractures south of the reef. A maximum radioactivity of 0.7 mr/hr was observed in a shallow shaft, and radioactivity of 4 mr/hr has been reported from this locality.

Silver Hill.--On Silver Hill, about half a mile north of Blackhawk, Gilpin Co., secondary fluorescent uranium minerals coat fracture surfaces and are disseminated in weathered biotite schist in a lead-zinc-silver vein deposit.

Maximum radioactivity recorded at the face of a partly caved adit was 3. mr/hr. The vein is moderately radioactive at the surface for a distance of over 500 feet.

South Platte River area.--High radioactivity is associated with brecciated and bleached hornblende gneiss in the southern part of Jefferson County, along the South Platte River. Uranium minerals have not yet been identified, but ore-grade material is reported from the area.

Wyoming

Park Range and Sierra Madre Mountains

Fair-U claims.--Since the examination in 1950 of the Fair-U claims on Fish Creek (Beroni and McKeown, TEI-308A), a 210-foot adit and 140-foot drift were driven to intersect radioactive zones at depth. Maximum radioactivity of 0.8 mr/hr is in the drift in coarse biotite-enriched zones along contacts of hornblende gneiss and pegmatite. This contrasts with a maximum radioactivity of 1.2 mr/hr at surface exposures. Two samples from the adit and drift contain 0.06 and 0.07 percent U.

Wind River Mountains

Whiskey Mountain.--Secondary uranium minerals are associated with purple fluorite and clay minerals in cavernous silicified rocks of probable Cambrian age on Whiskey Mountain, 6 miles south of Dubois, Fremont Co., Wyo. Radioactive material from near surface exposures contains from 0.015 to 0.030 percent eU.

Moon Lake.--Radioactivity is associated with biotite-rich zones in granite gneiss near Moon Lake, 7 miles southwest of Dubois. A sample of biotite-rich rock contains 0.015 percent eU. Nearby copper-bearing quartz veins are not noticeably radioactive and contain 0.003 percent eU.

Laramie Range

Esterbrook.--Pitchblende (?) has been found in a vein in Trail Creek, 6 miles north of Esterbrook. Moderate radioactivity was noted in a northeast-trending reef-type structure one-fourth mile south of the Trail Creek deposit. The reef consists of granite breccia in a jasperoid matrix.

Owl Creek Mountains

De Pass mine.--At the De Pass mine, sec. 14, T. 40 N., R. 92 W., a group of copper veins occur in granite and hornblende gneiss. A maximum radioactivity of 0.15 mr/hr is in chlorite schist, an alteration product from the hornblende gneiss. A selected sample of the chlorite schist contains 0.001 percent eU. The combination of rock units is similar to those considered favorable for uranium deposition in other parts of the pre-Cambrian in the Rocky Mountains. Although the area of exposed pre-Cambrian rocks in the Owl Creek Mountains is relatively small, the proximity of ore deposits in clastic sediments and intensely weathered granite along the south edge of the mountains suggests that other primary uraniferous zones may be found in the pre-Cambrian rocks.

Rock Springs Uplift

Two radioactive localities in clastic sediments were examined in the vicinity of the Rock Springs uplift. Near Superior in sec. 35, T. 21 N., R. 102 W., a tuffaceous, conglomeratic sandstone is exposed in what appears to be a channel type of deposit. The channel filling is radioactive (0.05 to 0.15 mr/hr); one grab sample of the material contains 0.045 percent U. The radioactive sandstone is in Cretaceous rocks that underlie the alkalic flows of the Leucite Hills.

In the vicinity of Little Mountain, T. 13 N., R. 105 W., several strata of intertonguing Green River shale and Wasatch sandstone are radioactive. Radioactivity of 0.1 mr/hr is fairly common in red sandy claystones that alternate with buff conglomeratic sandstones. Gray to blue-gray calcareous sandstones that form intermediate strata between the buff and red units are also radioactive. One of these gray sandstones is radioactive (0.05 to 0.15 mr/hr) for 600 feet along the strike and through a thickness of 12 to 18 inches. Maximum radioactivity of these gray sandstones is 0.5 mr/hr. A selected sample of the most radioactive material contains 0.018 percent U.

Wind River Basin

Along the south flank of the Owl Creek Mountains and the north edge of the Wind River Basin (Tps. 39 and 40 N., R. 92 W.) the Wind River formation and later tuff beds lap unconformably on the weathered, irregularly eroded surface of pre-Cambrian granite. Uranium minerals occur in sandstone and conglomeratic claystone of the Wind River formations in tuff and agglomerate that overlap the Wind River formation, and in the weathered granite that is overlapped by all of these rocks. The zones of greatest radioactivity follow valleys below the older unconformity. The granite is so altered as to affect migrating solutions as would an arkose, and the valleys on the old granite surface may provide the same structural effect as breached and overlapped anticlines in other areas.

One channel sample across a 2-foot stratum of sandy claystone contains 0.09 percent U; two grab samples from weathered granite and tuff contain 0.005 and 0.02 percent U. Several tons of material, reportedly of ore grade, have been stockpiled at one property.

Shirley Mountains
by J. D. Love

Uranium occurs in the Tensleep sandstone of Pennsylvanian (?) age as a yellow crystalline non-fluorescent mineral associated with calcite veins that cut vertically through the sandstone, in sections 30 and 31, T. 25 N., R. 81 W., and sec. 36, T. 25 N., R. 82 W. The sandstone is gray, fine-grained, cross-bedded, and composed almost entirely of quartz grains. The calcite veins range in thickness from a feather edge to 24 feet, with an average thickness of three feet. The length of some veins is more than 1000 feet and some cut vertically through the Tensleep sandstone escarpment for more than 500 feet. Yellow mineralization occurs in places in the higher parts of some veins and in the lowest exposures of others.

The area is one of complex minor faulting but the veins appear to be related not to the faults but to later tensional disturbance in the Shirley Mountains, which caused large fissures to open and to stay open for long intervals. These fissures were filled with crystalline calcite. This is an artesian structure and active springs now emerge at the foot of the Tensleep escarpment, from the lowest exposures of the calcite veins. Calcium carbonate is being deposited along some of these streams.

Two uranium minerals appear to be present. One is yellow, crystalline, and non-fluorescent. The other is green, crystalline, and non-fluorescent.

Physical exploration in the area is confined to several shallow test pits. A channel sample from one of these pits, through a vein width of two feet, contained 0.03 percent U. A selected sample from one pit contained 0.11 percent eU, 0.089 percent U, and less than 0.1 percent V_2O_5. A selected sample from an adjacent pit contained 0.35 percent eU, 0.39 percent U, and 0.25 percent V_2O_5.

The uranium minerals may have come from pre-Cambrian rocks at higher elevations to the northwest, where some radioactivity was observed, and were deposited by ground water flowing along fissures that opened in late Tertiary or Quaternary time. Some of the fissures are still open; others are filled with loess soil. The adjacent Madison limestone (Mississippian) shows evidence of extensive solution and is thought to have furnished much of the calcite that was deposited in the veins. Occurrences of copper minerals are common in the Madison limestone of this area and small amounts of radioactivity have been observed in association with the copper minerals.

Pedro Mountains
by J. D. Love

A uranium deposit associated with graphite occurs in pre-Cambrian rocks in the Pedro Mountains, NW$\frac{1}{4}$ NE$\frac{1}{4}$ SE$\frac{1}{4}$ sec. 14, T. 27 N., R. 84 W. Uranium appears to have concentrated in the vicinity of the graphite in much the same way that uranium in sandstone concentrates in the vicinity of carbonaceous material. The graphite layer was followed for several hundred yards and both uranium mineralization and spotty radioactivity were observed along this outcrop, in the granite on the under side of the graphite layer. An adit driven along the layer for about 30 feet shows that it is somewhat more than six feet thick, underlain by a thin gray quartzite (?), and intruded and surrounded by gray and brown granite.

Within the weathered zone, which extends downward for about 15 feet from the ground surface, yellow uranium minerals are abundant along fractures and disseminated through the granite within four to six feet of the graphite bed. A lesser amount of mineralization occurs in the quartzite (?) and the graphite shows some finely disseminated fluorescent mineral. Below the weathered zone is a concentration of sulfides, chiefly pyrite, but there does not seem to be more radioactivity where the sulfides are more abundant. The unweathered granite is bluish-gray, with large crystals of biotite and other ferromagnesian minerals and some finely disseminated black mineral that appears to contain uranium. A small shipment of ore has been made from the one operating mine.

In view of this occurrence of uranium concentrated in the vicinity of graphite, in pre-Cambrian rocks, it is suggested that perhaps other uranium deposits may occur in the vicinity of the six occurrences of

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graphite in the pre-Cambrian rocks of the Laramie Mountains, five in the Hartville uplift, one in the Medicine Bow Mountains, one in the Sierra Madre Mountains, and one in the Wind River Mountains.

Pinedale area
by J. D. Love

Extensive masses of pre-Cambrian granite in the vicinity of Fremont Butte, on the southwest flank of the Wind River Mountains show radioactivity that is several times background. One area more than one-fourth mile in extent shows radioactivity of 0.07 mr/hr or higher, within which are small localities where radioactivity reaches a maximum of 0.8 mr/hr. A sample of granite from N$\frac{1}{2}$ SE$\frac{1}{4}$ sec. 17, T. 32 N., R. 107 W., contains 0.015 percent eU and 0.002 percent U. A sample from the NW$\frac{1}{4}$ sec. 21, T. 32 N., R. 107 W., contains 0.030 percent eU and 0.002 percent U. A spectrographic analysis of this last sample shows 0.x values for titanium, cerium, lanthanum, neodynium, thorium, and zirconium.

The pre-Cambrian rocks were not examined along the remainder of the 100-mile length of the southwest flank of the Wind River Mountains except for a few localities east of Tabernacle Butte, 35 miles southeast of Fremont Butte, where pre-Cambrian granite shows readings of 0.03 to 0.08 mr/hr, with a background of 0.015 mr/hr.

Sandstones and conglomerates in the Wasatch formation adjacent to these areas of radioactivity in pre-Cambrian rocks show some localities where radioactivity is double background but they have not been examined in detail.

Nevada-Utah district
by J. F. Powers

Nevada

A uranium deposit and a low-grade uranium occurrence along the western flank of the Double H Mountains in northern Humboldt County were sampled and mapped. The Moonlight Mine has the only record of production in the area and the most extensive development program. Uranium minerals at this property are erratically distributed along an eastward-dipping fault that displaces Tertiary volcanic rocks. Uranium mineralization is spotty, but ore-grade material is present in the vein. Samples taken underground and on the surface show a range of from less than 0.02 percent U to 0.40 percent U. A recent examination of the property revealed a change of wall rock type from an altered volcanic rock to a granitic intrusive rock at a depth of 185 feet. At this stage, the outlook for the deposit seems promising.

During reconnaissance examination of the intrusive rocks of Eureka County, abnormal radioactivity was detected at one prospect in the Maggie Creek mining district, ten miles northwest of Carlin, Nevada. A sample taken at this prospect contains 0.05 percent equivalent uranium.

Utah

Geologic mapping and compilation of maps of the Wah Wah Range and Western Tushar Mountains, Beaver Co., were completed during the report period. Mapping shows that the most favorable places for uranium mineralization in these areas are close to shallow rhyolitic intrusives. Prospector interest in these areas is intense; however, the deposits that have been discovered are generally of marginal grade and probably contain only small tonnages.

In southern Iron County and Washington County, an area comprising twelve square miles was mapped. Here the uranium deposits are in breccia pipes of Kaibab limestone along the Hurricane fault. The pipes are at the intersection of a smaller set of faults with the main Hurricane fault. Sampling indicates that in four places along the fault there is a fair amount of ore-grade material. Twenty-eight tons of ore recently were shipped from one of the properties. Results of the settlement are not available at this time.

RECONNAISSANCE FOR URANIUM IN ALASKA

by J. J. Matzko

Areas investigated for radioactivity during the 1954 field season are shown in figure 50, and a brief summary of the results are shown in table 24.

Table 24.--Summary of reconnaissance for uranium in Alaska, June 1 - November 30, 1954

Region Locality	Designation on figure	Remarks
West-central		
Candle anomaly	DZ	Airborne radioactivity anomaly caused by a granitic talus with 0.005 percent eU.
East-central		
Tofty area	EG	Geochemical water sampling did not reveal any anomalies. Maximum uranium content 0.004 ppm from Manley Hot Springs.
Southwestern		
Kodiak Island	DW	Ground investigation did not duplicate samples of metatyuyamunite and meta-autunite received from prospector. Maximum radioactivity of samples was 0.003 percent eU on granite. Airborne radioactivity traverses of the island did not detect any anomalies. A few water samples collected for uranium analysis did not indicate any anomalies.
Southern		
Tyonek	CS	Airborne radioactivity traverse of the Fowler Carnotite area did not indicate any anomalies. See TEI-390, p. 223.
Yakataga	DU	Airborne radioactivity traverse of beach from Cordova to Juneau did not reveal any anomalies. Ground traverses in part of the area substantiated the airborne data. Water samples collected for uranium analysis did not show any anomalies and maximum obtained was 0.002 ppm U.

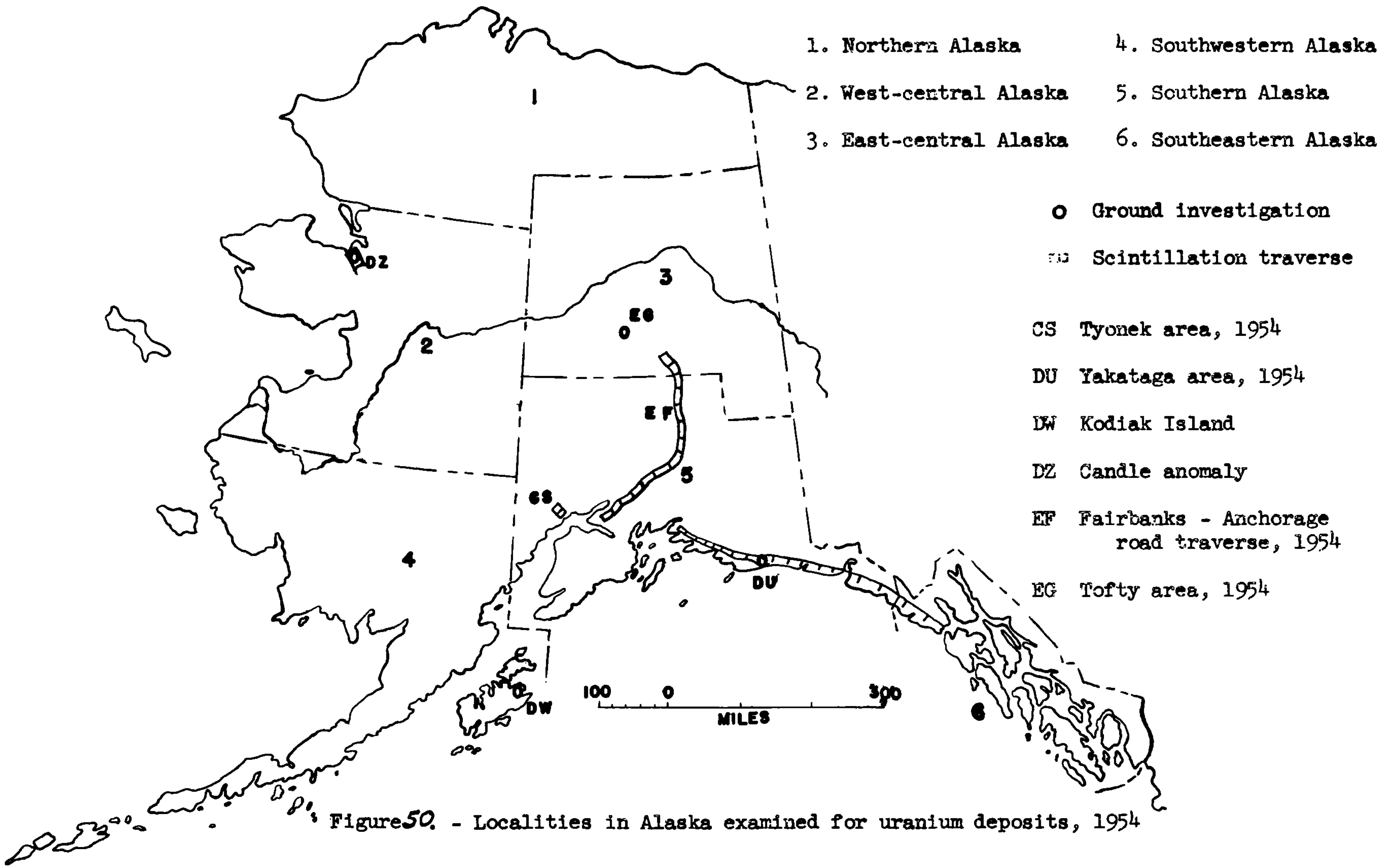

Figure 50. - Localities in Alaska examined for uranium deposits, 1954

Table 24.--Continued

Region Locality	Designation on figure	Remarks
Southern (Continued)		
Fairbanks-Anchorage	EF	Road traverse from Fairbanks to Anchorage via Alaska Tok cut-off and Glenn highways did not reveal any new anomalies. See USGS Circs. 184, 331, and 335.

Summary of laboratory work at College, Alaska during field season 1954

Determinations, equivalent uranium	305
mineral	100
spectroscopic	315
Heavy liquid separations	200
Alpha plate studies	15
Taxpayers, visitors and letters	60

ANALYTICAL SERVICE AND RESEARCH ON METHODS

Sample control and processing
by J. J. Rowe

On July 1, 1954, a new "Request for Analysis" form was adopted for field and laboratory use. The form provides for return of an acknowledgment of receipt of the samples at the laboratory, and an estimate by the laboratory of the completion date. It also provides for more detailed information concerning the analytical problems involved, thus permitting the laboratory to furnish more efficient and complete service to the field projects. The form is in use in both USGS and AEC units served by the USGS laboratories.

Adjustments were made in the distribution of work loads between the laboratories to promote more efficient operations through the equitable distribution of service requests.

Sample storage warehouses were provided by the USGS in Beltsville and in Denver. This will permit the orderly storage of the more than 250,000 samples that have been analyzed in the USGS laboratories.

Although the overall number of samples received from several of the large drilling and sampling programs decreased, there was no appreciable reduction in work load. This was caused by the change in type of work requested, from routine determinations on large numbers of samples to fewer but more difficult types of determinations on a greater variety of materials.

The analytical services for the AEC programs for the six months covered by this report are summarized in table 25.

Table 25.--Analytical work and sample inventory, Trace Elements Laboratories, June 1 - November 30, 1954

Source of samples	Analytical data: Chemical determinations: U	Chemical determinations: Others	Radioactivity determinations	Spectrographic determinations: No. Samples	Spectrographic determinations: No. Dets.	X-ray determinations	Number of samples: On Hand June 1	Rec'd 6/1 - 11/30/54	Completed 6/1 - 11/30/54	On Hand 12/1/54
Washington Laboratory										
Southeast Phosphates	2,686	849	10,945	39	307	10	5,497	7,360	11,038	1,819
AEC	351	103	181	49	3,332	110	7	377	295	89
Fuels	236	296	259	29	1,972	1	156	955	823	288
Northwest Phosphates	159	147	284	--	--	2	219	264	247	236
Uranium in Water	187	191	--	94	6,344	--	24	247	271	--
Alaskan Branch	11	32	1	8	544	3	2	111	43	70
Miscellaneous	597	484	163	302	12,377	78	286	815	846	255
Public Samples	512	11	645	20	1,360	40	126	1,359	959	526
Mineralogy Projects	89	176	--	226	14,832	167	15	643	492	166
Geochemistry of U.	813	291	236	176	4,428	126	434	903	964	373
Total	5,641	2,580	12,714	943	45,496	537	6,766	13,034	15,978	3,822
Denver Laboratory										
Colorado Plateau	744	1,811	1,164	236	8,437	17	369	2,169	1,295	1,243
Plants and Soils	1,610	188	18	--	--	--	330	2,083	1,618	795
Oil Well Drilling	--	--	--	--	--	--	72	6	--	78
Southeast Phosphates	229	--	500	--	--	--	475	--	475	--
AEC	2,138	1,586	3,348	135	8,100	60	809	3,924	3,613	1,120
Min. Dep. Reconn.	550	878	729	186	13,020	32	1,882	2,469	1,634	2,717
Fuels Branch	497	421	389	505	28,980	38	274	3,132	838	2,568
Public Samples	47	12	71	1	70	--	35	110	79	66
Miscellaneous	78	172	237	109	3,900	49	696	992	1,019	669
Total	5,893	5,068	6,456	1,172	62,507	196	4,942	14,885	10,571	9,256
Grand Total	11,534	7,648	19,170	2,115	108,003	733	11,708	27,919	26,549	13,078

Radioactivity

Analysis and services
by F. J. Flanagan

Routine radioactivity determinations are continuing and 12,889 such determinations were made during this period. Analytical data for both the chemical and radioactivity determinations of uranium in southeast and northwest phosphates were collected but calculations have been temporarily deferred because of higher priority of other work. Routine calculations of standard deviations of the differences between chemical and radioactivity determinations of uranium in southeast phosphates is continuing. "Tables for evaluating Bateman equation coefficients for radioactivity calculations" was published in the October 1954 issue of Analytical Chemistry.

A statistical design for testing the efficiency of three sample splitting methods was set up and calculations were made (see Research on methods and techniques in mineralogy and petrology). Radioactivity measurements were made on a suite of granites from the red and green quarries at Redstone, New Hampshire (see Distribution of uranium in igneous complexes) and it was shown that differences between the red and green granites occur.

Calculations involving radioactivity determinations of eighty-seven duplicate samples of a Chattanooga shale using the coaxial tube and sample holder show that the experimental standard deviation, 27 counts, is lower than the expected value, 35.5 counts. The latter value is obtained from the square root of the mean number of counts as the distribution of a series of counts of a large number of incidents fits the Poisson distribution which has the interesting property that the mean and the variance are equal.

Research - Washington
by W. R. Champion

Thorium analysis

Experimental work on the photographic alpha-star method of thorium analysis proceeded slowly. Because of eye strain, several hundred stars only can be counted under the microscope per day. The distribution of stars will be studied to see if the theoretical and experimental numbers agree and also to check thorium analysis using this method. Over a thousand 4- and 5-prong stars were counted during the last six months and the ratio of 4- to 5-prong stars is about 1.48. The theoretical ratio should 1.62. A statistical analysis is being made of the data.

Development work continued on the thoron method of thorium analysis. The greatest effort was expended in building a high temperature furnace for the very high temperature minerals. A furnace was designed and constructed using a carbon tube as the heating element and sample holder. It maintained a more than satisfactory temperature of 2600° C for several hours under operating conditions. It is planned to allow more time on this project in the future as other projects are completed.

Metamictization of zircons

No bombardments were made during the past six months, as the Oak Ridge National Laboratory's Cockcroft-Walton accelerator is being rebuilt. In the meantime three new targets were constructed for use on the new Oak Ridge accelerator. As the particles accelerated by this machine have a very short penetration range in zircon, the targets were made as thin as possible to permit production of an X-ray pattern that could be used to observe the metamictization. The samples were prepared by grinding in a mortar and sized by allowing them to settle in alcohol. The grain size was determined by electron diffraction. The targets were prepared by forcing the grains into a copper backing with a hydraulic press and consisted of a single layer of zircon grains approximately 2 microns in diameter.

Activation analysis

The mass spectrometric analyses of copper in the copper-silver "half-breed" given in TEI-440 were confirmed on the mass spectrometer. Two methods of activation analysis were attempted at Oak Ridge National Laboratory: (1) Measurement of the activities of Cu^{64} and Cu^{65} and determination of the abundance ratios by extrapolation back to zero time, and (2) weighing the total copper, measuring the amount of the 12-hour isotope by calibration with a standard, and finally obtaining the abundance ratio by difference. Preliminary tests indicate that method (2) is more accurate and suitable for routine analysis. Samples are being prepared for further tests.

Analysis and research, Denver
by J. N. Rosholt, Jr.

The laboratory made 6,119 eU determinations during the last half-year period. In addition, 78 radiochemical determinations of various daughter products were made including analyses for Th^{232}, Th^{230}, Ra^{226}, Rn^{222}, and Pb^{210}.

As a special project the Ra^{226} content of a 48-year-old (1906) thorium nitrate salt was analyzed with an accuracy of ± 5 percent using the radon train method. This salt will be used later for a redetermination of the half-life of thorium. A preliminary value for the half-life of Th^{232} was determined. A value approximately 10 percent higher than that described in the literature was obtained. The primary purpose of this determination is to provide an independent check for the half-life measurement by the ionization chamber method being performed by F. E. Senftle. More accurate determinations are now being made.

The paper describing the radiochemical analysis of Th^{232}, Rn^{222}, and Pb^{210} was published as "Quantitative radiochemical method for determination of major sources of natural radioactivity in ores and minerals," by J. N. Rosholt, Jr., Analytical Chemistry, Vol. 26, p. 1307, August 1954.

Spectrography

Spectrographic methods - Washington

Emission spectrography, by C. L. Waring

A revised table of standard sensitivities for the elements determined by the semiquantitative spectrographic analysis resulted from improved techniques and spectral line studies initiated during the reporting period. The new sensitivities are shown in table 26.

Additional progress was made on the spectrographic, microphotometric scanning project which is a modification of the semiquantitative method of analyzing mineral, rock, and ore samples. The method has been applied to lignite ash samples, being based upon evaporated liquids and solid synthetic and naturally occurring materials as standards. The results are reported to one decimal place for most of the 68 elements covered by the method, which is also being standardized for other types of materials.

The American Society for Testing Materials has suggested that the procedure for determining lead in zircon and other minerals, as used in the Larsen method of calculating ages of rocks, be submitted for publication

Table 26.--Standard sensitivities for the elements determined by the semiquantitative method (Washington Laboratory)

	%	
Ag	0.00001	
Al	0.0001	
As	0.01	
Au	0.001	
B	0.005	
Ba	0.001	
Be	0.00005	
Bi	0.005	
Ca	0.01	
Cd	0.005	
Ce	0.03	
Co	0.008	
Cr	0.006	
Cs*	0.01	(0.8)
Cu	0.00005	
Dy	0.006	
Eu	0.003	
Er	0.003	
F**	0.08	
Fe	0.0008	
Ga	0.004	
Gd	0.006	
Ge	0.001	
Hf	0.03	
Hg	0.08	
Ho	0.001	
In	0.0004	
Ir	0.03	
K*	0.005	(0.3)
La	0.003	
Li*	0.00003	(0.04)
Lu	0.005	
Mg	0.00003	
Mo	0.0005	
Mn	0.0007	

	%	
Nb	0.001	
Na*	0.003	(0.01)
Nd	0.006	
Ni	0.005	
Os	0.1	
P	0.07	
Pb	0.001	
Pd	0.003	
Pr	0.01	
Pt	0.003	
Rb*	0.007	(7.)
Re	0.04	
Rh	0.004	
Ru	0.008	
Sb	0.01	
Sc	0.001	
Si	0.005	
Sm	0.008	
Sn	0.004	
Sr	0.001	
Ta	0.1	
Tb	0.01	
Te	0.08	
Th	0.08	
Ti	0.0005	
Tl	0.04	
Tm	0.001	
U	0.08	
V	0.001	
W	0.07	
Y	0.003	
Yb	0.0003	
Zn	0.008	
Zr	0.0008	

* A second exposure is required for the high sensitivity listed.

** A third exposure is required for the fluorine estimation.

in Methods for Emission Spectrochemical Analysis. The method was applied to 125 samples.

A quantitative spectrographic method for the determination of strontium in phosphate rock was developed and applied to 32 samples.

The spectrograph was found to be an excellent tool for calibrating light filters. In cooperation with other chemical research projects, a number of Corning filters were calibrated. The transmission peaks were located in fluorimeter filters to be used in making uranium determinations. The data provided should aid in improving fluorimetric methods for determination of uranium.

Spectrographic studies of the hafnium-zirconium ratio were completed. The rapid method was designed to provide data to aid in further geochemical and radioactivity studies. A total of 168 samples were analyzed.

Approximately 50,000 spectrographic qualitative, semiquantitative, and quantitative determinations were completed on 865 samples during the report period.

Infrared spectroscopy, by R. G. Milkey

During the report period the versatility of the infrared spectrophotometer was increased by addition of (1) the cesium bromide prism, which more than doubles the usable range of the infrared spectrum compared to that obtained with the sodium chloride prism, (2) the calcium fluoride prism, which has a resolving power, in some regions of the infrared spectrum, of up to three times that obtained with the sodium chloride prism, and (3) the infrared polarizer, which provides polarized infrared light and thus is of great use in ascertaining the direction of bonds and spatial arrangements in crystals.

The performance of the infrared spectrophotometer was tested with the calcium fluoride prism installed, and spectra thus obtained were compared with those of the sodium chloride prism. The calcium fluoride prism proved chiefly valuable in resolving the sharp rotational spectra of gases. For the broader absorption bands of the liquid and solid samples, acceptable resolution generally was obtained with the normally used sodium chloride optics.

Procedures for analyses were improved, particularly the method of sampling by use of potassium bromide imbedding windows, and additions were made to the library of infrared standard data. On hand are close to 3,000 standard spectra of organic and inorganic substances, several thousand abstracts of the current literature, and approximately 150 reprints of the most pertinent articles in the literature.

A wide variety of samples were analyzed, both in support of the objectives of other projects and for purposes of research and analyses of interest to the infrared spectrography program. Organo-uranium extracts from lignites, coals, black shales, and oil-impregnated sandstones, were analyzed in order to determine the unit structures of the extracted material, and to compare similarities of structure in the different extracts. Highly complex in structure, all of the organo-uranium extracts show the presence of substituted benzene rings or vinyl type of carbon-carbon double bonds, and several carbonyl bonds such as aldehydes, ketones, or esters. Other unit structures variously present include hydroxyl (both hydrogen-bonded and unbonded), the carbon-hydrogen bond (both aromatic and aliphatic), and carboxylic groups. Additional spectra of such samples will be obtained in the continuing study of uranium-bearing carbonaceous rocks.

Hectorite samples from Hector, California, were analyzed for evidence of the type of lithium bonding in the crystal. The spectra indicate that the lithium does not substitute into the silicate layer, as they contain absorption peaks that are known to arise from unsubstituted silicate layers as with the absorption spectra of montmorillonite and nontronite.

Analyses were made to determine the structural identification of synthetic zircons, thorites, and huttonites, the determination of possible hydroxyl substitution into silicate structures, and to investigate polished glass samples. The last study was made to ascertain whether changes in structure accompanied changes in the index of refraction resulting from increased hydration of the samples.

A comprehensive study to obtain spectra of all available vanadium compounds and minerals was begun, with the objective of correlating the absorption peaks of vanadium compounds in various forms. The spectra so far obtained indicate that at least two significant absorption peaks in the wavelength interval from 9.8 to 12.0 microns are characteristic of all the vanadates. A similar study will be made with uranium compounds and minerals.

Spectrographic methods - Denver
by A. T. Myers

During the past six-months period, a total of 62,504 determinations were made on 1,182 samples submitted for analysis by projects of the Raw Materials Program.

As a part of an investigation on quality of analysis, a selected group of samples was analyzed quantitatively for thorium. The precision and probable accuracy of the spectrographic analyses are shown in table 27.

Table 27.—Comparison of spectrographic, radiochemical and X-ray fluorescence thorium analysis

Sample Number	SPECTROGRAPHIC 1st Detn percent	2nd Detn percent	3rd Detn percent	Mean percent	S. D.	C.V. percent	Ave. Th percent	Radiochemical Th percent	X-ray Fluorescence Th percent
1	0.124	0.105	0.130	0.119	0.013	10.9	0.12	ndt	0.122
2	.175	.175	.170	.173	.0029	1.67	.17	.17	.182
3	.510	.464	.470	.481	.025	5.20	.48	.49	.483
4	.720	.660	.720	.700	.034	4.85	.70	.66	.753
5	.990	.990	1.02	1.00	.017	1.70	1.00	.96*	.990

* By radiometric determination

The mean, standard deviation(S. D), and coefficient of variability(C. V.), have been calculated. The precision of the spectrographic method includes a reproducibility study where each measurement represents successive determinations made on the same sample ground to less than 100 mesh. X-ray fluorescent and radiochemical results on the same samples are also shown in table 27 for comparison. Excellent agreement between these three independent methods of analysis is indicated. The spectrographic method in brief involves weighing 30 mgms. of the minus-100-mesh sample previously ground in agate with two times its weight of pure carbon powder. All the other conditions and details of the method are described in TEI-179, p. 29.

One result of the use of the semi-quantitative method as developed in the USGS laboratory at Denver is a preliminary report on the "Distribution of elements on the Colorado Plateau," by E. M. Shoemaker, W. L. Newman, A. T. Miesch, and R. G. Havens. This study shows that significant studies on element distributions in geologic provinces are now possible by the application of this method.

As a result of a study being undertaken in the spectrographic laboratories of the Geological Survey, to investigate the limits of element sensitivities, the element sensitivity chart for the Denver laboratory was modified. This is the result of a change in the photographic developing technique for spectroscopic plates.

The three-meter Hilger grating spectrograph delivered July 1953 but severely damaged in shipment was repaired and installed for operation by the company representative. This instrument is now ready for routine quantitative analysis.

TEI-179 and TEI-417 dealt with grinding of rock samples by a vertical type grinder, first with steel plates and then with ceramic plates. Quantitative spectrographic analysis was used for determining the amount of contamination introduced into the sample from steel alloying elements in the steel plates. Finally, when the alumina ceramic plates proved a successful substitute for steel plates, further spectrographic analyses were made on experimental samples (quartz and quartzite), ground by alumina ceramic plates. The results showed the effectiveness of the ceramic plates in preventing rock sample contamination (TEI-417). As a result of these studies of contamination a separate grinding laboratory was installed to keep metal contamination at a low level while grinding a large number of rock samples for spectrographic and chemical analysis; a bucking board and muller made of similar ceramic material was obtained and found to be a very satisfactory substitute for steel for this method of grinding.

Chemistry

Analysis of raw materials - Washington
by Irving May

The level of analytical activity remained substantially the same as that of the previous report period. Samples now being analyzed tend to be in smaller lots and of a more varied nature, and an increasing number of requests for analyses involve deadlines. These factors have made it difficult to apply mass production techniques.

The accompanying table (table 28) presents a breakdown of the determinations completed. It should be noted that approximately one-third of the determinations are for other than chemical U and ash.

Table 28.--Breakdown of completed determinations, Washington Trace Elements Laboratory, June 1 - November 30, 1954.

Determination	Completed the Past Six Months
U	4562
Ash	260
Al	53
Fe	59
Ca	280
P	636
Th	9
S	49
F	270
Oil	134
Loss on ignition	62
Total Solids	173
Acid Insoluble	60
Organic Matter	124
Miscellaneous	303
Total	7034

USGS Bulletin-1006 entitled "Collected papers on methods of analysis for uranium and thorium," compiled by F. S. Grimaldi, Irving May, Mary H. Fletcher, and Jane Titcomb, was published. A paper "The effect of ashing temperature on the volatility of germanium in low-rank coal samples," by C. L. Waring and W. P. Tucker (TEI-267) was published in Analytical Chemistry, vol. 26, no. 1198, 1954.

The study of the determination of small amounts of zinc in rocks, initiated in the previous report period, was completed. No new analytical methods were evolved.

Determination of selenium in pyrite and marcasite was studied. Changes were made in the method and distillation apparatus to improve the determination in such samples.

A chemist was trained to perform micro-organic carbon and hydrogen determinations.

Three visitors from universities visited the laboratory for consultation on methods for determining uranium.

Analysis of raw materials - Denver
by L. F. Rader, Jr., and Wayne Mountjoy

A total of 11,604 determinations were made on 9,315 samples. Approximately half of the determinations were for uranium, about 12 percent each were for vanadium, calcium carbonate, and heavy metals, and the remainder were for miscellaneous determinations. Rapid analytical service for the drilling operations conducted by the Denver AEC office and the USGS Colorado Plateau Program is still the most important function of the laboratory. Of the 9,315 samples, 9,123 were routine and 192 were special samples. The distribution of service for the routine samples was 28.3 percent for the Denver AEC, 22.2 percent for the USGS Plateau Program, 22.5 percent for the Marysvale, Utah program, and the rest for miscellaneous projects including taxpayer samples. The Geochemical Prospecting Laboratory, which is not supported by AEC funds, made several hundred analyses in support of the AEC geological program.

Laboratory work on the study of ashing procedures prior to the determination of uranium in plants, coals and other carbonaceous materials was completed.

A series of studies on the use of low grade schroeckingerite from Lost Creek, Wyoming to form solutions from which the uranium could be absorbed by low rank coals were made.

Studies on the use of citric acid-ammonium citrate solutions to remove the carbonate cement characteristic of many sandstone samples are under way. The ammonium citrate solution at a pH of 5-6 dissolves relatively large amounts of calcium carbonate.

Research on analytical methods

The determination of fluorine in silicate rocks, by Blanche Ingram and F. S. Grimaldi

A method for the determination of fluorine in silicate rocks was developed and is in general use.

The method incorporates the use of a $ZnO-Na_2CO_3$ flux which insures the elimination of about 99 percent of the SiO_2 as insoluble zinc silicate.

Elimination of the interference of aluminum, which in the usual procedure retards the distillation of fluorine, was accomplished by complexing the aluminum with H_3PO_4. This modification allowed the routine application of this method to Florida leached zone samples. Many previously available methods were faulty when applied to samples that contain aluminum as a major constituent.

The procedure as developed also was applied successfully to micro amounts of fluorine and even to silicate rocks containing small amounts of fluorapatite. The microtitration technique, the alizarin colorimetric, and the thorin colorimetric procedures for measuring the fluorine content were in good agreement.

Analytical chemistry of thorium, by Mary H. Fletcher and R. G. Milkey

Work is continuing on the study of the analytical chemistry of thorium with attention focused on the fluorescence of the thorium-morin system. Laboratory tests were made to accumulate more data and clarify several points. A paper entitled "A fluorimetric study of the thorium-morin system," being prepared by R. G. Milkey and M. H. Fletcher, will give the results of the fluorimetric study, evaluate the fluorescent system as a basis for the quantitative determination of thorium, and present some of the theoretical and mathematical relationships between fluorescence and light absorption as exhibited in the thorium-morin system.

Determination of uranium by the spectrophotometric method, by H. I. Feinstein

Laboratory work on the thiocyanate method for the determination of uranium is practically complete. Early in the study it was found that the stability of the system is a function of both the acidity and the thiocyanate concentration. Consequently, these two factors were investigated simultaneously and optimum conditions were established for the development of the uranyl thiocyanate color.

The application of the method to uranium ore samples necessitated a study of the ethyl acetate extraction of relatively large amounts of uranyl nitrate from aluminum nitrate-nitric acid solution. It was found that amounts of uranium up to 100 mg. could be quantitatively extracted and that by a combination of washing and re-extraction the interference of vanadium could be eliminated. Results showed excellent agreement with AEC values on standard samples and with results by conventional volumetric methods.

Determination of lead in monazite, by R. A. Powell

Past experience in the determination of lead in monazite indicates that results obtained by chemical and spectrographic methods are not in close enough agreement for certain applications. In order to check the accuracy of chemical methods, lead is being isolated from spiked monazite samples for independent lead determinations by the isotope dilution method.

In order to meet the continuing need for the isolation of several milligrams of lead, as iodide, from small samples of monazite, several methods for recovering lead are being used concurrently for a comparison of efficiencies.

Lead determinations on monazite samples from various sources are being made chemically and spectrographically as a further check.

Separation of carbon from fossil bone for C^{14} determination, by Irving May

A method was developed for isolating carbon (for C^{14} determination) from fossil bone by pyrolizing the sample in a nitrogen atmosphere and then removing extraneous material from the carbon by treatment with HCl and HF.

An apparatus for the multiple fusion of uranium flux pads, by C. A. Kinser

An apparatus for the multiple fusion of uranium flux pads, consisting of a battery of six bunsen burners assembled with standard pipe fittings on an asbestos covered base was constructed. It is enclosed on three sides and vented at the top with an aluminum hood. Two pieces of vycor tubing are mounted so that they support flux dishes over the flame.

This apparatus proved to be very helpful in multiple fusions by maintaining steady flames which are necessary at this critical step in uranium analyses.

A pipette drying device, by H. I. Feinstein and I. H. Barlow

A simple and practical pipette drier was constructed, by use of which pipettes can be dried in 3 to 5 minutes. This represents a considerable saving in time over the usual one or two days required for pipettes to dry when inverted in a drying basket or the several hours required to dry them in a large drying oven.

GEOCHEMICAL AND PETROLOGICAL RESEARCH ON BASIC PRINCIPLES

Distribution of uranium in igneous complexes
by E. S. Larsen, Jr.

Research was continued on all aspects of the problems concerning the distribution of uranium in igneous rocks. Chemical, mineralogical, sampling and field studies were conducted on rocks and minerals from the following areas:

Chemical Investigations

Modoc Lavas, California:

These lavas which underly an area of nearly 100 square miles, are relatively young, ranging from Miocene to Recent in age. Their chemistry and field relationships have been described (Powers, H., Amer. Min. v. 17, 1932).

Table 29.--Uranium Content of the Modoc Lavas, California.

Rock types	No. of samples	Range of U content (ppm)	Average U content (ppm)
Obsidian	7	4.8 - 7.3	5.6
Rhyolite	4	1.3 - 4.9	2.8
Dacite	2	3.9	3.9
Basalt	8	0.22- 3.6	0.88
Andesite	3	2.0 - 6.0	4.0
Pumice	1	4.7	4.7
Slag	1	86.0	86.0

Boulder Batholith, Montana:

Field, chemical, and petrologic studies of this batholith are nearly completed. Underlying an area of approximately 1200 square miles, the batholith is composed essentially of quartz monzonite.

Table 30.--Uranium content of the Boulder batholith and associated rocks

Rock type	No. of Samples	Range of U content (ppm)	Average U content (ppm)
Quartz monzonite	33	0.8 - 15.0	3.5
Andesite	7	1.9 - 3.4	2.7
Rhyolite	5	2.5 - 12.7	4.8
Dacite	5	2.0 - 3.1	2.6
Quartz porphyry	1	16.6	16.6
Glassy dike rock	1	20.0	20.0
Gabbro	1	1.0	1.0
Basalt	1	0.73	0.73

Highwood and Bearpaw Mountains, Montana:

The Highwood Mountains are one of a group of highly mafic and highly potassic rocks and occupy an area of about 400 square miles. Similar rocks lie to the northeast in the Bearpaw Mountains and elsewhere in Montana. In the Highwoods, the oldest igneous rocks are the quartz latites. They underlie the mafic phonolites with a time difference between the eruption of the two groups of rocks. The quartz latites have about the same uranium content as the Potosi volcanic rocks of the San Juan Mountains of Colorado.

The potash-rich mafic rocks are not very high in uranium, but considering their mafic character they might be so considered. In such a series granites might have a high uranium content.

Table 31.--Uranium content of rocks from the Bearpaw Mountains

Rock type	No. of samples	Average U content (ppm)
Biotite apatite pyroxenite	1	1.1
Mafic monzonite	2	1.8
Monzonite	1	4.5
Porphyritic syenite	1	1.9
Mafic nepheline shonkonite	1	4.8
Nepheline shonkonite	1	5.3
Mafic nepheline syenite	1	5.0

Table 32.--Uranium content of rocks from the Highwood Mountains, Montana

Rock type	No. of samples	Range of U content (ppm)	Average U content (ppm)
Quartz latites	2	2.9 - 4.2	3.6
Mafic phonolites			
dark lavas and dikes	17	1.5 - 3.2	2.4
light lavas and dikes	1	4.1	4.1
Alnoite	2	3.4 - 3.7	3.5
Shonkonites and related rocks	11	1.5 - 4.6	2.6
Nilingongite	1	6.28	0.28
Syenite	3	2.2 - 5.5	3.5
Contact rock of Shonkin Sag	1	7.1	7.1
Transition rocks	4	1.9 - 6.1	4.2

Sierra Nevada, Bishop, California:

Table 33.--Uranium content of the rocks from Bishop, California

Rock type	No. of samples	Range of U content (ppm)	Average U content (ppm)
Orthoclase-albite granite	4	1.4 - 3.8	3.3
Lamark quartz-monzonite	4	3.0 - 5.6	4.6
Basin Mountain qtz.monzonite	7	1.4 - 6.1	3.2
Pine Creek qtz. monzonite	3	1.5 - 7.8	4.4
Wheeler Crest qtz. monzonite	2	1.9 - 3.3	2.6
McMurray qtz. monzonite	2	1.8 - 2.6	2.2
Tinemaha qtz. monzonite	4	3.1 - 4.8	4.6
Palisades granodiorite	2	1.7 - 2.7	2.2
Rock Creek granodiorite	1	2.9	2.9
Tungsten Hills granodiorite	1	1.8	1.8
Hornblende gabbro	2	0.3 - 0.54	0.42

Table 34.--Uranium content (ppm) of minerals from rocks from Bishop, California

Rock type	Albite granite	Pine Creek qtz. monz.	Lamark qtz. monz.	Basin Mt. qtz. monz.	Palisade grano-diorite
Orthoclase	1.3	1.6	0.64	0.68	0.44
Quartz	2.3	2.3	1.1	2.4	1.8
Plagioclase		1.3	1.1	1.5	0.80
Biotite	16.0	16.0	2.0	60.0	4.4
Hornblende		14.0	2.7		4.7
Augite					16.0
Monazite	640.0				
Zircon	710.0	180.0	730.0	1200.0	
Sphene	660.0	430.0	460.0		
Apatite		38.0	60.0		
Allanite	50.0			78.0	
Magnetite	9.0	6.9	1.0	11.0	2.3
Epidote					180.0

Table 35.--Alkalic rocks, Sussex County, New Jersey

Rock type	No. of samples	Range of U content (ppm)	Average U content (ppm)
Nepheline syenite	4	13.0 - 46.0	20.0
Porph. nepheline syenite	1	33.0	33.0
Nepheline porphyry	1	20.0	20.0
Bostonite	2	18.0 - 25.0	22.0
Bostonite porphyry	1	19.0	19.0
Ouachitite	1	6.0	6.0
Tinguite	1	8.0	8.0

Table 36.--Uranium content of rocks from the Idaho Batholith

Rock type	No. of samples	Range of U content (ppm)	Average U content (ppm)
Granite	4	1.5 - 6.3	2.8
Quartz monzonite	5	0.4 - 3.4	1.7
Granodiorite	7	0.5 - 4.8	2.0
Quartz diorite	4	1.4 - 3.1	2.0
Gneissoid rocks	8	0.5 - 3.3	1.8

Table 37.--Uranium content (ppm) of minerals from rocks of the Idaho Batholith

Rock type	Muscovite granite	Porphyritic granodiorite	Porphyritic gneiss	Quartz diorite	Grano-diorite
Quartz	0.80	0.74		0.62	0.11
Orthoclase	0.36	0.94	0.63		0.18
Plagioclase	0.96	1.3		5.0	
Hornblende				3.0	0.06
Biotite	2.9	0.34	1.9	58.0	7.0
Apatite	28.0	41.6	15.0	35.0	0.18
Magnetite	0.36	1.8	11.0		
Muscovite	5.4		2.2		
Garnet	6.4				
Monazite	1070.0				274.
Zircon	2400.0		400.0		
Xenotime	7630.0				
Sphene		170.0	108.0	300.0	
Flourite	0.49				
Epidote			63.0		
Ilmenite		10.0			1.6

Field investigations

Boulder Creek Batholith, Colorado

Previous uranium analyses on rocks from this batholith indicated a ten-fold enrichment in rocks from the western border facies. The uranium content of the rocks ranges from about 1 ppm to 14 ppm U near the border. The distribution of rock types and their spatial relationships were mapped during the past field season. The batholith is complex with a northern and western margin of gneissic quartz diorite. Away from this border the rocks are transitional to granodiorite, quartz monzonite, and small bodies of granite. The predominant rock type is quartz monzonite. Thus, the uranium is higher in the more mafic rocks and low in the most siliceous rocks. One hundred and fifty rock samples were collected for petrographic, mineralogic, and uranium studies from the representative rock types and from critical areas to ascertain the effects of assimilation of the various intruded rock types and its effect on the distribution of uranium in the batholith. In numerous outcrops of the more siliceous rocks allanite is very abundant with crystals ranging up to two inches in length.

A reconnaissance was made of the Mt. Evans batholith, Colorado, which is correlated petrographically with the Boulder Creek batholith. In this batholith an unusual opportunity was presented for obtaining samples from elevations of nearly 7,000 feet to over 14,000 feet. The main mass of the body is a coarse quartz monzonite. A well foliated quartz diorite was found around the southern and eastern margins of the batholith.

Conway granite of the White Mountain Magma Series

A detailed collection of the Conway granites was made preliminary to an intensive investigation of the distribution of uranium in the rocks and minerals. Study of the radioactivity of the red and green phases at Redstone, New Hampshire showed a large amount of local variation within small areas. Weathered rock showed higher radioactivity than fresh. Statistical studies showed significant differences between the red and green, and between the fresh and weathered phases. The radioactivity and the Th:U ratio was found to be higher in the weathered rock than in the fresh. The red phase has consistently higher radioactivity and uranium content than the green phase. Uranium, rather than potassium or thorium, is proving to be the principal variant in accounting for differences in radioactivity.

Research on methods and techniques

Investigations have continued on the use of the gamma ray spectrometry for obtaining thorium to uranium ratios. Several rocks on which the thorium and uranium contents are known will be used to test the new technique. Other samples of average igneous rocks on which the uranium and potash contents are known will be tested for their thorium content.

Weathering, transportation, and redeposition of uranium
by R. M. Garrels

Chemical work was completed on a channel sample from the Mineral Joe mine, Jo Dandy mining area. The results show that oxidation is superimposed upon the original mineralization. Apparently oxidation in this mine occurred through the agency of moist air because there is no indication from the samples of any migration of uranium or vanadium. The boundary of the mineralized zone, as revealed by chemical analyses and semi-quantitative spectrographic analyses, is extremely sharp. With the exception of a very small and constant uranium and vanadium anomaly the unmineralized sandstone is similar to "average unmineralized Salt Wash sandstone". In the ore zone there are strong positive anomalies for uranium, vanadium, iron, lead, barium, and strontium, and weak positive anomalies for molybdenum and copper. The overall picture is entirely consistent with a primary low valent mineral assemblage that has been oxidized in situ by atmospheric oxygen.

Mineralogic work on the channel sample is being continued.

The Eh-pH apparatus ran almost continuously during the report period. Work was done both on the oxidation state of the channel samples from the Mineral Joe mine and on oxidation-reduction studies of pure vanadium compounds. Results to date give a rough check on the theoretical diagram for the stability of the vanadium oxides (Some thermodynamic relations among the uranium oxides, and their relation to the oxidation states of the Colorado Plateau, Robert M. Garrels, Am. Min., v. 38, nos. 11 and 12, pp. 1251-1265, Nov.-Dec., 1953.). It also was demonstrated that vanadium in solution oxidizes and reduces with ease even at 25° C. This suggests that natural oxidation processes take place at high rates and are dependent chiefly on the presence of an oxidant.

Crystallographic work on various vanadium compounds was continued to help in the understanding of the mechanics of the oxidation processes. The most important contribution to date is the demonstration that all paramontroseite (V_2O_4) must be derived from oxidation of original montroseite ($V_2O_3 \cdot H_2O$). Paramontroseite is very common in the "blue-black ores".

Work continued on the vanadiferous clays. From the rate of release (by acid treatment) of various cations it can be demonstrated that most of the vanadium is in the structure of the clay minerals. The valence state of the vanadium is either V^{+3} of V^{+4} in the relatively few samples studied. There are probably three vanadium-bearing silicates: roscoelite, or true vanadium mica; vanadiferous hydrous mica; and vanadiferous (?) chlorite.

The work will continue chiefly on (1) experimental checks on the validity of the theoretical stability diagrams of the uranium-vanadium oxides; (2) preparation of vanadium and uranium compounds under controlled oxidation conditions to check the interpretation of the oxidation processes from mineralogic and chemical studies of the ores; and (3) further studies of the vanadiferous clay minerals in an attempt to decipher their chemical characteristics and their role in the genesis of the ores.

During the report period, TEI-455, "Some thermodynamic relations among the uranium oxides, and their relation to the oxidation states of the Colorado Plateaus" was issued and a manuscript on "Weathering of uranium ores" was sent to the American Mining Congress for publication. The material in this paper was presented at the September meeting of the American Mining Congress.

Mineral synthesis
by G. J. Jansen

The detailed work on the CaO-V_2O_5-H_2O system under atmospheric conditions is almost finished. The system was not investigated above pH 9 owing to the difficulties caused by the precipitation of $Ca(OH)_2$(?) and $CaCO_3$ (CO_2 entered the solution from the atmosphere). At 30°C and pH values of less than 9, the following phases occur:

3	2	1
Colorless	$2CaO \cdot V_2O_5 \cdot 2H_2O$	pH 9 to 8
Colorless to yellowish (rossite)	$CaO \cdot V_2O_5 \cdot 4H_2O$	pH 8 to 6.2
Orange (pascoite)	$3CaO \cdot 5V_2O_5 \cdot 16H_2O$	pH 6.2 to 2.3
Reddish to black (hewettite)	$CaO \cdot 3V_2O_5 \cdot 9H_2O$	pH 6.2 to 2.3
Dull brown, green, or black	$V_2O_5 \cdot xH_2O$	pH 2.3 to 0

At higher temperatures, some of the phase boundaries are changed in respect to pH, and new phases (pyrovanadates?) appear. The exact boundary between pascoite and hewettite phases is hard to determine. The formation of pascoite may depend on the rate of evaporation and thus pascoite may form in the hewettite stability ranges if the solution is concentrated rapidly by evaporation. Under usual evaporation conditions at 30°C, pascoite will crystallize from pH 6.2 to 2.3 but occasionally hewettite will form between pH 3 and 2.3. At higher temperatures the hewettite becomes increasingly stable until at 80°C the pascoite no longer forms, except when the rate of concentration is exceedingly fast. It is possible that under equilibrium conditions hewettite instead of pascoite is the stable phase between pH 6.2 to 2.3 at 30°C.

Progress was made in determining the solubility of carnotite under various controlled environments. A new procedure was devised that almost eliminates equipment failure, eases the operator's work, and insures more accurate results. Data were collected on ten solubility determinations. These determinations, using synthetic carnotite, were conducted under a controlled atmosphere and at temperatures of 30°C and 50°C. To vary conditions of pH and solubility, NO_3^-, SO_4^- OH^-, and CO_2 were introduced, individually, for various determinations. The pH ranged from nearly 8 to 3.2.

From the work now completed, it seems that the solubility of carnotite is very low, of the order of 0.1 to 0.2 ppm in distilled water. A more acid or basic environment increases the solubility. When the pH is as low as 3.3, the amount of carnotite which will dissolve is increased by about 20 fold or more, depending on what anions are present. Various anions may form complex ions with the uranium, increasing the solubility of the carnotite. An increase in the temperature also increases solubility in distilled water; thus, a rise of 20°C causes the concentration of uranium to increase nearly 50 percent. In the next few months, the effects of other common anions and cations in the solubility of carnotite and tyuyamunite will be studied.

Work was continued on the $Na_2O \cdot SiO_2 \cdot ZrO_2 \cdot H_2O$ system at 500°C. A total of 75 runs were completed in an attempt to delineate the stability regions of the four stable solid zirconium continuing phases. The regions, Na_2O (3-15%), SiO_2 (0 to 15%) and ZrO_2 (0 to 5%) were investigated. To date, zircon has not appeared as the stable phase in this section of the diagram. It would thus seem that zircon is unstable with respect to sodium zircono-silicates in the presence of Na_2O at 500°C. Elpidite is one of the solid phases encountered and its stability is still under investigation.

It was determined that hastalloy C high pressure bombs do not stand up well with long runs at 500°C. Half of the bombs failed, and the project has been slightly retarded pending the completion of replacement bombs.

Attempts to synthesize zircon from HF solution were successful. Crystals large enough for X-ray identification were grown. Experiments in large bombs were made in an attempt to duplicate earlier runs where zircon was grown on a large zircon seed. In all these runs difficulties occurred with bomb leakage and failure. These experiments will be repeated with additional equipment that is now available.

Isotope geology and nuclear research, Washington

Geochronology
by L. R. Stieff

The 6-inch mass spectrometer used for lead isotope analysis continues in routine operation. Following discussions with the National Bureau of Standards' Statistical Laboratory and members of the USGS, a sample control system was set up to follow the performance of the mass spectrometer. A method of lead-ratio calculations suggested by members of the Statistical Laboratory is being used. It represents a simple least square solution for all of the isotopic data obtained. On a series of duplicate analyses of lead iodides previously run by the Mass Assay Laboratory, Oak Ridge, Tennessee, agreement was obtained in all cases within 1.0 percent and usually within 0.5 percent of the lead-ratio reported. Approximately twenty analyses on USGS samples were completed.

The age studies on the Colorado Plateau are nearing completion. As part of this program, 18 specimens of black, unaltered Plateau uranium ores were prepared, and analytical work was completed on 12 of these specimens. Ninty-seven specimens of galena from the Plateau and surrounding areas were prepared in conjunction with the Plateau age studies and isotopic analyses were completed on 22 samples. Three age determinations on two specimens of high-grade carbonaceous uranium ores and one sample of asphaltic pellet ore from Temple Mountain, Utah, are of particular interest as they indicate ages of 76, 65, and 60 million years respectively. During October, supplementary specimens of galena and primary uranium ores, which had not been studied previously, were collected from a number of localities on the Colorado Plateau.

In addition to age work on Plateau uranium ores, a number of age studies were undertaken in cooperation with other USGS projects. Insofar as possible the laboratory geologists participated with the field geologists requesting the age determinations in collecting samples for analysis. Under these circumstances specimens were obtained from Mauch Chunk,Pennsylvania, the Wet Mountains, Colorado, the Chico Hills, the Raton area, New Mexico and the Globe district, Arizona. Age determinations also are being made on uraninite from the Peekskill Quadrangle, New York and from the Coeur d'Alene district, Idaho.

As part of the USGS contribution to the Mass Standards Program of the National Bureau of Standards, a large sample of Ivigtut galena was obtained from the Pennsylvania Salt Manufacturing Company. Twelve hundred grams of pure galena cleavage fragments were hand picked, crushed and thoroughly mixed. This sample and an additional 1,400 grams of relatively pure Ivigtut galena to be used in the preparation of lead were made available to the National Bureau of Standards.

Stable isotopes
by Irving Friedman

A new laboratory in Washington for the study of stable isotopes was completed toward the end of this report period, and the hydrogen-deuterium mass spectrometer was set up. Work on the portable mass spectrometer for volcanic gas analysis progressed to the point where it has been possible to make preliminary tests of its operation. The electronics and gas inlet systems are being revised and it is expected that this instrument will be ready for field operation by spring.

Nuclear geology
by F. E. Senftle

The extraction of chromium from uranium-vanadium ore proved to be exceedingly difficult in view of the small quantities present. After considerable effort, 10-15 mg. of chromium hydroxide was extracted and is presently being prepared for mass spectrographic analysis.

To test the possible fractionation of isotopes by natural diffusion processes a number of copper-bearing specimens were picked for isotopic analysis. It is hoped that under certain conditions of diffusion a change in the abundance ratio will be evident. Samples are being prepared for this study.

The study of adsorption of radioactive Cs^{137} ions on natural and synthetic quartz was terminated. In general, adsorption was greater on the faces of natural quartz crystals rather than on synthetic crystals. This appears to be partially caused by unidentified differences in surface texture. In some cases a strong spot adsorption took place at the center of spiral growth patterns, and this would seem to confirm the theory that centers of spiral growth patterns are elongated cavities perpendicular to the direction of growth. Some correlation between crystal imperfections and adsorption were demonstrated.

Isotope geology of lead

by R. S. Cannon, Jr.

Did the composition of lead in the earth at one time resemble the primitive sort of lead that C. C. Patterson succeeded in isolating from two iron meteorites? This problem is fundamental to understanding the variations in isotopic composition of the lead that occurs in rocks and minerals of the earth's crust. It is possible to calculate how the isotopic composition of lead in the earth may have evolved through geologic time, measuring backward from the kinds of lead now found, and using what evidence there is of the present abundance of lead, uranium, and thorium in the earth's crust. One hypothesis that can reasonably be drawn from such calculations is that earth-lead something like 4.6 billion years ago may have resembled the kind of lead now found in meteoritic troilite. Even the most primitive sample of earth-lead reported to date, in galena from the Transvaal, South Africa, does not approach very closely in composition the lead from iron meteorites (table 38). But if this hypothesis of evolution of lead in the earth is more or less correct, it should be possible to find in the lithosphere some more direct evidence. A quest for such evidence is in progress in cooperation with Patterson and associates in the geochemical laboratory of the California Institute of Technology.

Table 38.--Illustrative isotope analyses of lead

Ref.	Sample	Pb composition (atomic ratios) 206/204	207/204	208/204
1.	Canyon Diablo meteorite (troilite)	9.41	10.27	29.16
2.	Galena, Rossetta mine, Transvaal, S. Afr.	12.65	14.27	32.78
3.	Olivine bomb, Hawaii, #PO-52H4	19.29	15.45	37.95
4.	Basalt, Shoshone, Idaho, #Id-5L-Sbf	18.12	15.45	38.08
5.	Galena, Uintah Co., Utah, #U-U-VBC	25.96	16.45	46.38

One can investigate the traces of lead present in those few kinds of rocks that can be suspected of having formed as integral parts of an original crust or mantle of a primitive earth. Among such materials currently under study are (1) an olivine bomb from Hawaii, carried up from the interior of the earth by an outpouring of basaltic lava, (2) a feldspathic bomb (troctolite) from the same Hawaiian lava flow, (3) a second olivine bomb from Peridot cinder cone in eastern Arizona, (4) a sample of Marcy-type anorthosite from the Adirondacks, N. Y., and (5) troilite from northern California, the only locality where this kind of iron sulfide has been reported to occur as a terrestrial mineral. Patterson extracted and analyzed lead from the terrestial troilite and from the Hawaiian olivine bomb (table 38). These leads do not resemble lead from iron meteorites in isotopic composition--rather they are similar to lead in some samples of galena--but their significance cannot be interpreted satisfactorily until the ratio of lead to uranium and thorium in these samples can be measured. To obtain a nearly independent line of evidence on the geologic history of anorthositic rocks, efforts are being made to concentrate enough zircon for age determination by the Larsen method from anorthosite, both from the Adirondacks and from the San Gabriel Mountains, California.

A search also can be made from earth-lead of primitive isotopic composition in crustal rocks known to be of extreme antiquity, from the combined evidence of stratigraphy and lead/uranium age determinations. Analyses of rather primitive lead in galenas from Wyoming and Southern Rhodesia were previously reported; subsequent work was concentrated on rocks of the Bulawayan series of Southern Rhodesia. The latter were shown to be older than 2.65 billion years in a recent paper by Holmes (Nature, April 1954). At present, work continues on three rocks collected by

Dr. A. M. Macgregor of Southern Rhodesia from the Bulawayan series. They are a pillow basalt, an algal limestone, and a pyritic graphitic slate. Recently, Patterson obtained an isotopic analysis of lead extracted from the pillow basalt. This lead was not of primitive composition, but its significance cannot be interpreted until the ratio of lead to uranium and thorium in the sample has been determined.

Lead in the earth evolved during geologic time by the generation of new atoms of lead from radioactive decay of uranium and thorium. As the evolution of lead must have proceeded at different rates in different geological environments, so the kind of lead today in one environment can be expected to differ from that in another environment. Yet almost as little is known about the isotopic composition of present-day lead in various environments on the earth as about the composition of primeval lead from which the evolution supposedly started some billions of years ago. In this direction some progress is being made on the composition of lead in modern basaltic magmas by study of samples from recent lava flows. Work is in progress on the basaltic matrix that encloses the dunite and troctolite bombs from Hawaii (1800-1801 flow, Hualalai Volcano) and from Arizona (Peridot lava flow). Study of a third recent basalt, from the Snake River Plains of Idaho, was completed, and the isotopic composition of lead extracted from it is reported in table 38.

These studies of traces of lead in rocks are complemented by concurrent studies of lead in lead minerals and ores. Chemical work on galena samples has been done in the Washington USGS laboratory and the lead isotope analysis at the Mass Assay Laboratory, Oak Ridge. A recent analysis of considerable interest is one of lead from a sample of galena from

Mississippian limestone on the south flank of the Uinta Range, Uintah County, Utah. This lead has isotopic characteristics similar to the "anomalous" lead from Joplin galenas but exhibits an even more extreme abundance of the three radiogenic isotopes. Although the geologic significance and origin of lead of this type is still unknown, continuing geologic evaluation of data like this should give a clue. This analysis is listed in table 38 together with other illustrative analyses.

Crystallography of uranium and associated minerals

by H. T. Evans, Jr.

Significant advances were made in crystal chemistry and structure studies of uranium and vanadium as it applies to the Colorado Plateau. Outstanding results are described briefly in the following sections.

Crystal structure of liebigite

It has been known for a long time that the fully oxidized uranyl ion will form a very stable soluble complex with carbonate. When uranium is dissolved and carried in ground waters, it probably is in the form of this complex. By a crystal structure study of liebigite, $Ca_2UO_2(CO_3)_3 \cdot 10H_2O$, which is one of several soluble carbonates found in the Plateau, the constitution and structure of the complex ion $UO_2(CO_3)_3^{----}$ have been derived. It consists of the linear UO_2^{++} group in association with three triangular CO_3 groups in a plane perpendicular to the O-U-O axis, so that two oxygen atoms from each CO_3^{--} group are bonded to the uranium atom to form a hexagon around it. The carbonate groups lie in a crystallographic mirror plane in the liebigite crystal.

Crystal structure of rutherfordine

The crystal structure of rutherfordine, UO_2CO_3, was determined. It has a layer structure in which all the CO_3^{--} groups lie in parallel alinement in a plane, with the UO_2^{++} groups inserted in the hexagonal holes so that they are perpendicular to the plane and joined to two oxygens in each of two carbonate groups and one oxygen in each of two others. The bonding configuration for the UO_2^{++} ions is identical to that found in the isolated ion group in liebigite, and it is inferred that the sheet structure is built up by a condensation process from the $UO_2(CO_3)_3^{----}$ complex ions under oxidizing hydrothermal conditions. Therefore, rutherfordine is common in oxidized Belgian Congo specimens where such conditions existed, and the soluble carbonates are rare, whereas in the Colorado Plateaus where weathering processes prevail, soluble carbonates are more common and rutherfordine is very rare.

Crystal structure of $K_2V_6O_{16}$

The crystal structure of artificial $K_2V_6O_{16}$ was solved. The insoluble orange crystals of this substance are formed when the potassium decavanadate solutions are heated or aged. The structure is a sheet arrangement containing elements of the five-fold coordinated metavanadate chain found in $KVO_3 \cdot H_2O$, whose structure was determined in detail a year ago. The vanadium-oxygen coordination is more assymmetric in $K_2V_6O_{16}$, one type of vanadium being five-fold, the second type approaching six-fold as in V_2O_5.

Other vanadate structure studies

The composition of the decavanadate complex, represented by the Colorado Plateaus minerals hummerite and pascoite, was firmly established by crystallographic studies, but its structure, which is being studied through a crystal structure analysis of hummerite, has not yet been ascertained.

A new vanadium mineral from the Peanut Mine, Colorado was received. Studies indicate that it has a layer structure, and is apparently related to several other minerals by an interesting series of ion substitutions:

New mineral	$CaV_4O_9 \cdot 5H_2O$
Sincosite	$CaV_2P_2O_{10} \cdot 5H_2O$
Meta-autunite	$CaU_2P_2O_{12} \cdot 5\text{-}7H_2O$
Metatyuyamunite	$CaU_2V_2O_{12} \cdot 5\text{-}7H_2O$

The relation of the new mineral (which contains only tetravalent vanadium) to the oxidation sequence in the oxide ores is of great interest. Studies are being continued.

Radon and helium studies
by A. P. Pierce

New occurrences of uranium-bearing asphaltite, considered to be a source of radon, have been noted in drill cuttings of rocks ranging from lower Pennsylvanian to upper Permian in age, and extending along the entire length of the Amarillo-Wichita uplift, as shown in figure 51.

An occurrence of uranium-bearing asphaltite in outcrops of the upper Permian Seven Rivers formation near Carlsbad, New Mexico is being investigated. Asphaltite pellets, together with "live oil" and asphalt, are found in secondary openings such as fractures, bedding planes, stylolites,

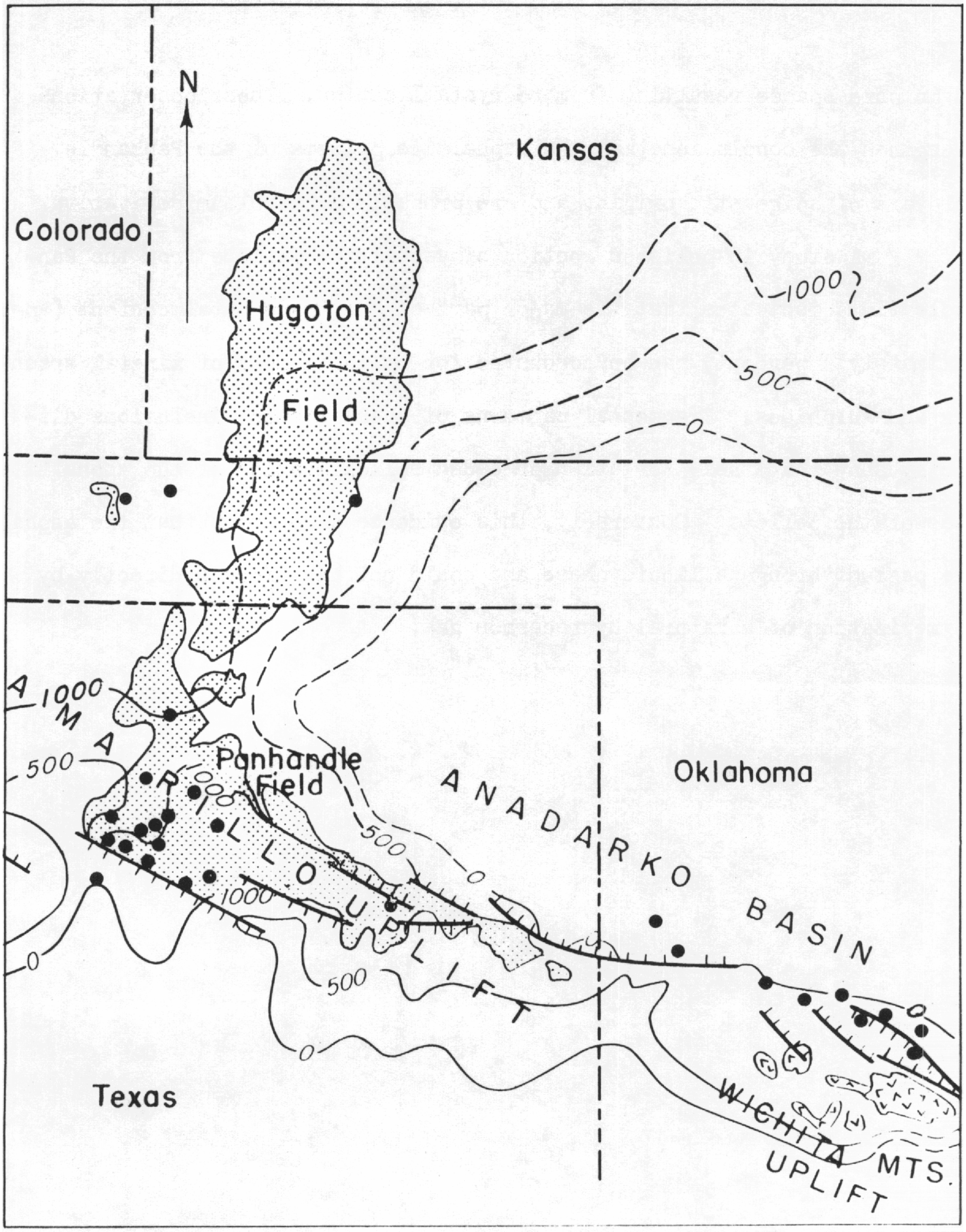

FIGURE 51 -MAP OF AMARILLO-WICHITA UPLIFT SHOWING LOCATION OF OIL AND GAS WELLS IN WHICH ASPHALTITE PELLETS HAVE BEEN FOUND. STRUCTURAL CONTOURS ON PERMIAN "BIG LIME" AND EQUIVALENT FORMATIONAL TOPS.

50 0 50 Miles

and in pore spaces resulting from recrystallization. These observations strengthen the conclusion that the asphaltite pellets of the Panhandle field are of epigenetic origin, and are probably a petroleum derivative.

A study in polished section of asphaltite pellets from the Panhandle field indicates that the major part of the trace metal content (approximately 5 percent) can be accounted for by inclusions of mineral arsenides and sulphides. Fragmental patterns of these mineral inclusions distinctly show that their formation preceded solidification of the asphaltite phase of the pellets. Conversely, this evidence also shows that the asphaltite passed through a liquid phase and could not have formed directly by polymerization of a natural hydrocarbon gas.

MINERALOGIC AND PETROGRAPHIC SERVICE AND RESEARCH

Services

Mineralogic services, Washington
by E. J. Dwornik

Public sample program

Approximately 1350 samples were analyzed for radioactivity during this report period. About twenty percent of these samples required more detailed analyses, such as mineralogical, chemical, X-ray, and spectrographic. There has been an increase of approximately 700 submitted samples since the last report period.

Special sample program

Twenty-one reports entailing mineralogic and petrologic analyses were prepared for field geologists engaged in radioactivity reconnaissance.

All analyses were completed on a sample of yttrium- and cerium-earth-bearing apatite from Essex County, New York and a draft of a paper reporting results prepared for publication.

A report is in preparation concerning a new yttrium mineral from Dover, New Jersey. A spectrographic analysis detects yttrium as the only element present in quantity greater than 10 percent.

Apparatus for vacuum differential thermal analysis was constructed in collaboration with the project on "Geochemistry of uranium-bearing carbonaceous rocks." This equipment has the following operating parameters: rate of rise of temperature of the furnace (0-40°C/min); sample size (0-150 mg.); amplification of differential curve; operation under vacuum, air, or inert or controlled atmosphere. Standardization of the apparatus is nearing completion and it soon will be available for routine and research work.

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Mineralogical services, Denver
by L. B. Riley

During the report period 210 samples were processed in the Denver mineralogy laboratory. As the majority of these samples were fine-grained aggregates, many of which were secondary uranium and vanadium minerals, X-ray techniques were generally needed for identification. Three hundred and fifty-seven X-ray powder diffraction photographs and 58 X-ray diffractometer analyses were made. Optical and other mineralogical study techniques were used, mainly in the differentiation and separation of the various minerals in the submitted specimens prior to applying X-ray procedures.

Liebigite and uraninite from the Gas Hills, Wyoming area, and uraninite and paramontroseite from the Pumpkin Buttes, Wyoming area were identified. In both of these occurrences the uraninite was closely associated with pyrite. Native bismuth, possibly associated with uraninite, was identified in specimens from Ralston Creek, Jefferson County, Colorado. A high-uranium lignite sample submitted from the Cave Hills, South Dakota area contained tyuyamunite. The same mineral, with autunite, has been tentatively identified in a siltstone from Dawes County, Nebraska.

Analysis for thorium X-ray fluorescence demonstrated that this is a very practical method; the range studied was from 0.01 percent thorium to 1.00 percent thorium. In the 0.01 to 0.03 percent thorium range the reproducibility shows a standard deviation of 0.003 percent thorium. Ten samples in the 0.25 to 1.00 percent thorium range, submitted by the Denver AEC office, gave very close agreement with percent eTh results. In anticipation of extending the use of the X-ray fluorimeter, extensive tables were calculated for use with LiF analyzing crystals.

X-ray services, Washington
by George Ashby

During the reporting period 670 determinations were made on 513 samples. In the same interval the existing methods of indexing powder data were reviewed and a program of evaluation of these methods were started.

Two cameras, a Philips micro-camera for very small samples and a de Wolff focussing camera for high resolution in the forward reflection region, were used for the first time.

Electron microscopy
by E. J. Dwornik

The electron microscope laboratory has undertaken routine examination and identification of fine-grained materials as well as several special research projects.

The study of metamict minerals was directed toward gaining additional information regarding the nature of the metamict state. Initial examination showed that crystalline regions do exist in metamict zircon and that good electron diffraction patterns could be obtained. This study was extended to include other metamict minerals.

A study of 22 species of vanadium- and uranium-bearing minerals was continued. Electron micrographs and electron diffraction patterns using both the selected area diffraction attachment and the electron diffraction unit were obtained. In instances where morphology and size of individual crystals were favorable, reciprocal lattice patterns were photographed for reference in structure work.

The determination of the accuracy and precision obtained in measuring electron diffraction patterns was carried on. Tentative values were obtained for errors inherent to the photographic reproduction of patterns and also for the degree of accuracy in measuring the diffraction rings with the modified measuring microscope.

A total of 380 electron micrographs and 180 diffraction patterns were added to the reference library.

Research

Research on techniques in mineralogy and petrology
by E. J. Dwornik

Statistical studies of sample splitting using the microsplit, the cone splitter, and hand quartering were continued in cooperation with the radioactivity analysis and services program. Because preliminary statistical analysis indicated significant differences among the methods, precision and accuracy of the three methods were compared. Calculations in enumeration statistics were carried out using the statistic chi square (χ^2) to rank the three methods for both precision and accuracy. These tests show that the microsplit is the least precise and least accurate, and that cone splitting is most precise and most accurate.

Tests are being conducted to obtain information concerning the comparative mineral composition of micro-splits of a sample having extremely small percentages of one constituent. The purpose of this study is to determine, if possible, the optimum size of a split required to assure a mixture representative of the whole sample.

The results of grain counts on heavy mineral separates commonly are converted to weight percent by assuming that all grains in a given sieve fraction are the same size, and that the weights of individual grains are directly proportional to their density. A check on the assumption of uniform size was made by determining the average weight per grain of a number of minerals by direct measurement, then comparing the weight percent of each mineral in various mixtures determined by the "density" method with that obtained by using samples with measured weights per grain. Statistical methods show that the results obtained from using the average weight per grain give a much better estimate of the known composition, and that results by the "density" method may be seriously in error.

Models of the cone sample splitter have been used by the Denver Laboratory of the USGS, the Geochemistry Department of the California Institute of Technology and the Beach Erosion Board of the U. S. Corps of Engineers. A rapid uniform method of sampling a slotted cone sampler was designed and constructed. This instrument is a hollow stainless steel 60° cone having four narrow slots. Approximately 10 percent of a sample drops through these slots into standard carton containers as the whole sample is poured onto the apex of the cone. Sampling tests are now being designed to establish the accuracy and precision of the method.

A successful method for removal of barite from zircon has been found. These minerals are not separated by standard heavy mineral separation techniques because of virtually identical specific gravities, resistance to acids, and lack of magnetic response. To study the radioactivity and lead content of zircon, all barite must be removed. Barite (1) may contain alpha activity produced by radium and its daughter products and (2) may contain Pb^{++} substituted for Ba^{++}. Thus, alpha activity and lead measurements of zircon concentrates may be completely invalidated by the presence of small amounts of barite. To separate barite from zircon, the sample is treated in boiling 2N Na_2CO_3 to change barium sulphate to carbonate, which is readily dissolved in concentrated HCl.

Removal of -400 mesh fines from ground samples is effected by elutriation with distilled water in a Jones reductor. Approximately 90 percent of the fines removed will pass a 400 mesh sieve. The method has been used for removal of fines prior to mineral purification of mica, amphibole, magnetite, and pyroxene.

Properties of uranium-bearing minerals
by Alice D. Weeks

"Studies of uranium minerals: Rutherfordine, Diderichite, and Clarkeite," by Clifford Frondel and Robert Meyrowitz was issued as TEI-474.

Three vanadium minerals associated with uranium in the Colorado Plateau ores were analyzed chemically by Robert Meyrowitz. These include volborthite $Cu_3(VO_4)_2 \cdot 3H_2O$, corvusite (?) $V_2O_4 \cdot 5V_2O_5 \cdot 8H_2O$, and a new calcium hypovanadate, $CaV_4O_9 \cdot 5H_2O$. Analysis of synthetic "voglite" showed it to be a mixture.

At the American Chemical Society meeting in September 1954, Rovert Meyrowitz presented a paper entitled "Immersion liquids of high index of refraction containing arsenic tribromide as the solvent."

GEOPHYSICAL PROSPECTING AND RESEARCH

Development and maintenance of radiation detection equipment

by W. W. Vaughn

Research and development

A highly sensitive gamma-ray logger using a $1\frac{1}{2}$" x 2" sodium iodide crystal and DuMont photomultiplier tube was constructed. The equipment is mounted in a Jeep station wagon. The instrument is capable of logging holes 2,000 feet deep at logging speeds up to 30 feet per minute, the principal parts of the unit being the scintillation probe, reel, British type N522 counting ratemeter, and Esterline-Angus one milliampere recorder. Preliminary tests of this equipment in the Black Hills region showed that a difference of 0.001 percent equivalent uranium content of the strata could be easily distinguished on the recorded graph. Experimental measurements are presently being made in order to prepare a calibration chart of counting rate versus percent equivalent uranium.

Construction of a core scanner (TEI-440) utilizing a liquid phosphor is nearing completion. Considerable difficulty was experienced in obtaining proper sealing of the phosphor. Plastic phosphors which have recently become available will be used in the future.

A modification of the carborne scintillation counter circuit to provide total intensity counting was tested. The statistics were very poor, which would indicate that in this type of circuit the random pulse height combines in some manner with the random occurrence of radiation to adversely affect the statistics of the counting rate.

An instrument was constructed to be used as an "emanation differentiator". The instrument is pulse-height sensitive and is basically a device for timing and identifying pulses relative to their occurrence in a decay chain.

A mixing circuit to channel the output of photomultiplier tubes connected in parallel is under test. This circuit incorporates silicon diodes for loading and decoupling the various phototubes in the combination.

Modification and maintenance of equipment

A Tracerlab automatic sample changer is being modified for use as an automatic sampling device. A phototube and phosphor arrangement will be used to view the sample, replacing the conventional GM tube. The number of samples the instrument will accommodate will be reduced from the original 25. However, the features of predetermined time and count, as well as automatic sample positioning with relation to the phosphor, will be retained.

Preamplifiers to be used with ionization chambers for alpha counting are being redesigned and modified. The modifications will bring about uniformity, eliminate undesirable oscillations and in general render the equipment more serviceable for the application.

A test program for screening and categorizing G-M tubes for X-ray apparatus used by the Geological Survey was set up. Modification of the present equipment so as to use a scintillation head as the sensitive element is being studied.

Airborne radioactivity surveying

by R. M. Moxham

Airborne radioactivity surveys totalling 35,622 traverse miles were undertaken in eight states and the Territory of Alaska, as follows:

State	County	Area	Traverse miles
Alaska		Candle Creek	400
		Buckland-Kiwalik	220
		Yakataga Beach	300
		Tyonek	340
		Nutzotin	320
		Nixon Fork	190
Arizona	Mohave	Arizona Strip	680
Colorado	Moffat	Washakie Basin	5320
Maine	Aroostook	Devonian Belt	3170
	Piscataquis	Devonian Belt	800
Montana	Blaine	North Bearpaw	3100
Oklahoma	Caddo	Wichita Mountains	744
	Comanche		2660
	Greer		15
	Kiowa		2533
	Tillman		380
Pennsylvania	Monroe	Mauch Chunk	565
	Carbon	Mauch Chunk	750
Utah	Kane	Arizona Strip	2730
	Washington	Arizona Strip	160
	Uintah	Myton	765
	Duchesne	Myton	620
Wyoming	Natrona	Pine Mountain	1910
	Converse	West Pine Ridge Escarpment	1095
	Niobrara	East Pine Ridge Escarpment	1770
	Sweetwater	Washakie Basin	745
	Converse	Tisdale	215
	Natrona	Tisdale	2525
	Johnson	Tisdale	600
		Total	35,622

The Alaskan surveys (fig. 52) included areas of widely variant geologic conditions ranging from beach placer deposits (Yakataga beach) to

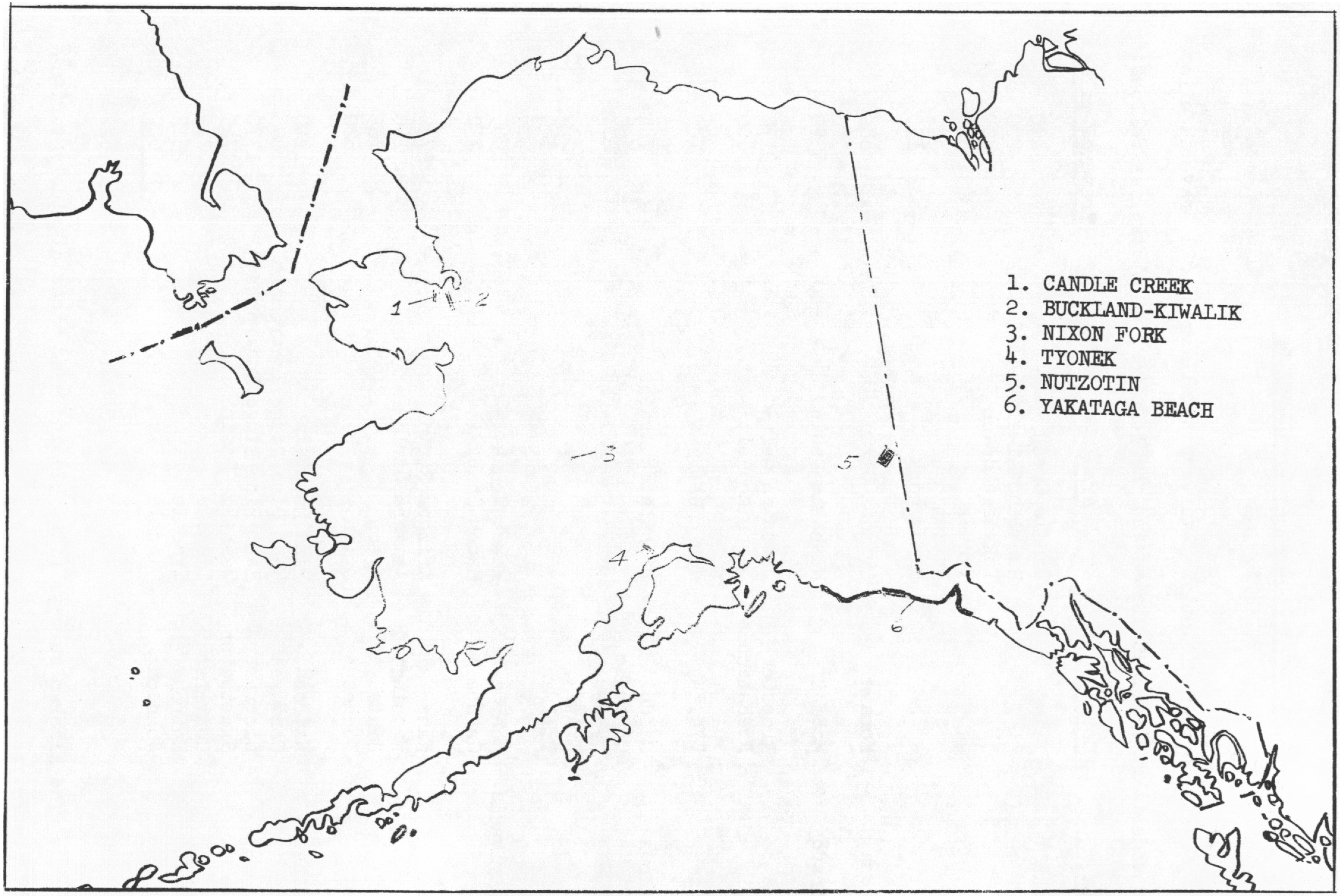


Fig. 52
AIRBORNE RADIOACTIVITY SURVEYS IN ALASKA

vein deposits (Nixon Fork). The results were not encouraging. Abnormal radioactivity was detected at only one locality in Alaska, near Candle, in the Candle Creek area. Ground reconnaissance revealed only an area of granite float.

No anomalies were detected in the Arizona Strip survey in Arizona and Utah (fig. 53), which is underlain mainly by the Chinle and Shinarump formations. The survey was seriously hampered by irregularly distributed fall-out.

Surveys in the Washakie Basin area (fig. 53) of Colorado were designed to extend previous coverage of the Browns Park (Miocene (?), formation.. Uranium mineralization in this formation was first noted as a result of an airborne survey in November 1952 (TEM-606). The area was extended by a survey in November 1953 (TEM's 743-7) which resulted in the discovery of additional mineralization in the Browns Park. Surveys during the present reporting period indicate additional mineralized localities in an area of about 150 square miles north of the Yampa River between Maybell and Craig. The anomalies are for the most part in areas underlain by the Browns Park formation. Preliminary field investigation of approximately half of the airborne radioactivity anomalies indicate the existence of several ore-grade deposits of significant tonnage.

Rocks of Tertiary and Eocene age occupy the Myton area, Utah (fig. 53). Abnormal radioactivity was recorded at several localities in an area of about 25 square miles 8-10 miles south of Myton.

The Pine Mountain, Tisdale and Pine Ridge Escarpment areas (fig. 54) are underlain chiefly by Cretaceous and Tertiary sedimentary rocks. Four widely scattered anomalies were detected in the East Pine Ridge

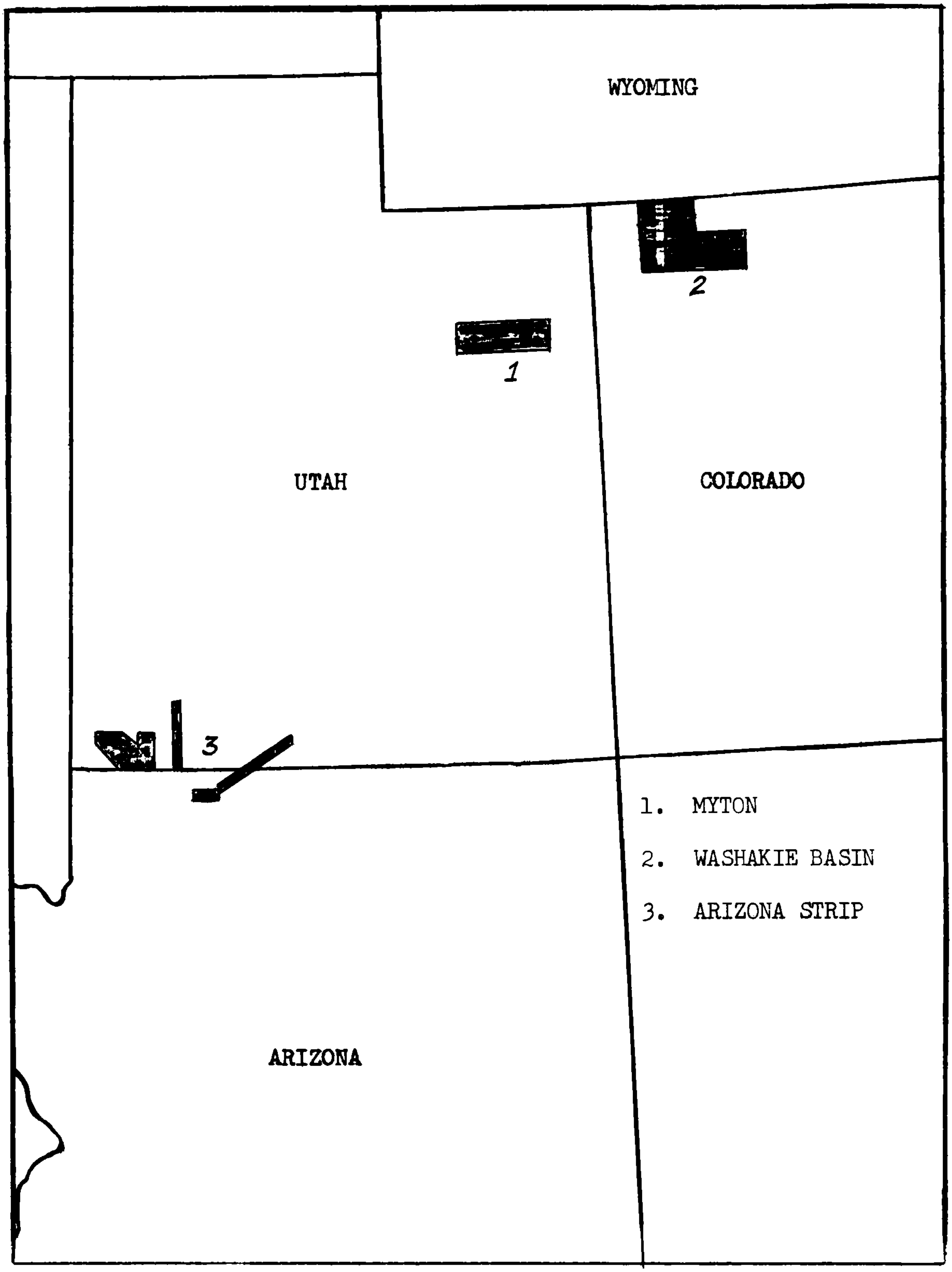


Fig. 53

AIRBORNE RADIOACTIVITY SURVEYS IN ARIZONA, COLORADO AND UTAH

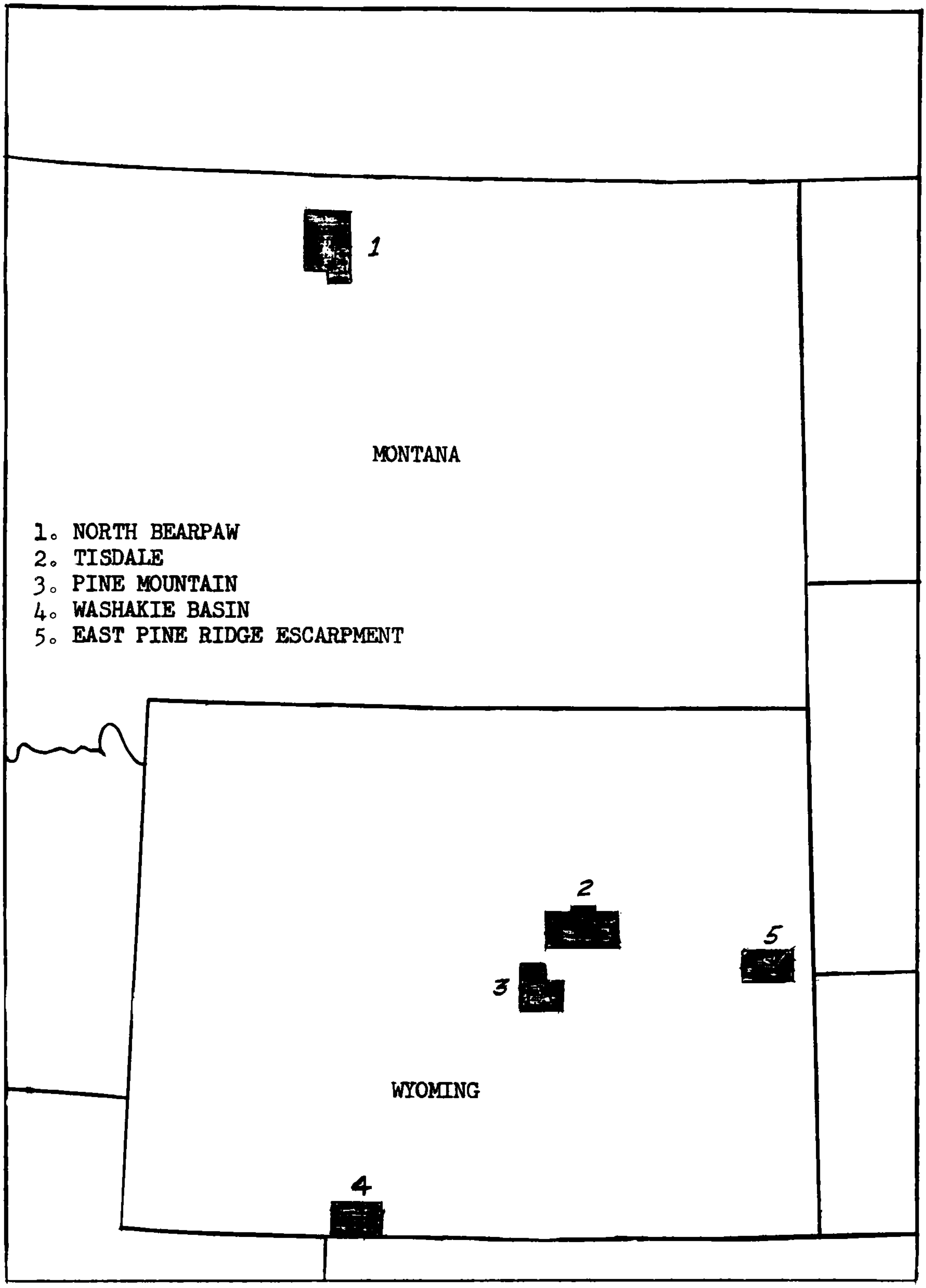


Fig. 54

AIRBORNE RADIOACTIVITY SURVEYS IN MONTANA AND WYOMING

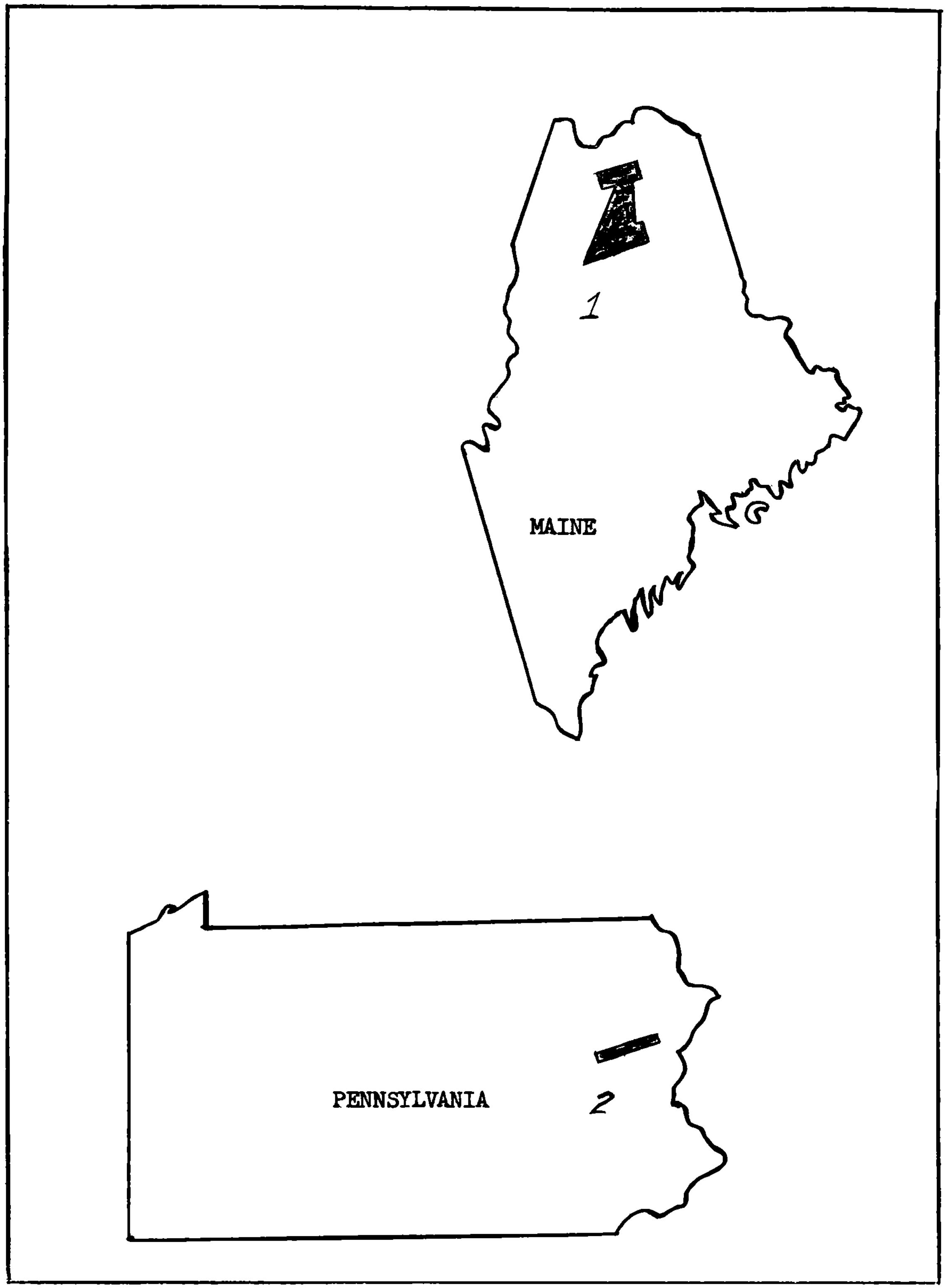
Escarpment area, three in the Lance formation, the fourth in the Mowry or Bell Fourche formation. One anomaly was recorded in the Tisdale area, on the southeast flank of the Salt Creek anticline, apparently produced by a radioactive zone in a basal sandstone of the Lance formation. The material appears to be less than ore grade. One anomalous area was found in the southern part of the Pine Mountain area. No anomalies were recorded in the West Pine Ridge Escarpment or Washakie Basin areas.

The North Bearpaw area, Montana (fig. 54) includes chiefly the Bearpaw and Judith River formations (Upper Cretaceous). No anomalies were recorded.

The Maine Devonian belt (fig. 55) is underlain chiefly by volcanic rocks, meta-sedimentary strata and granitic intrusive rocks. The Devonian belt extends northeastward into Canada, and contains pitchblende deposits at Campbellton, New Brunswick. An anomalous area was detected in the surveyed area near Three Brooks Fire Tower. Slightly radioactive meta-volcanic rocks were found at this locality during a brief ground investigation, but do not appear to be entirely responsible for this anomaly. Exposures are poor and additional ground work is required.

The Mauch Chunk area (fig. 55) is underlain by sedimentary rocks ranging in age from Devonian to Pennsylvanian. Uranium deposits occur in the Catskill formation at Penn Haven Junction, and in the Pottsville formation at Mauch Chunk (USGS Circular 350). The airborne survey was not successful in finding new deposits. A few very small anomalies were detected but nothing of significance was found on the ground.

Granitic intrusive rocks form the core of the Wichita Mountains, which intrude Permian redbeds (fig. 56). Uraniferous asphaltite pellets



1. DEVONIAN BELT
2. MAUCH CHUNK

Fig. 55
AIRBORNE RADIOACTIVITY SURVEYS IN MAINE AND PENNSYLVANIA

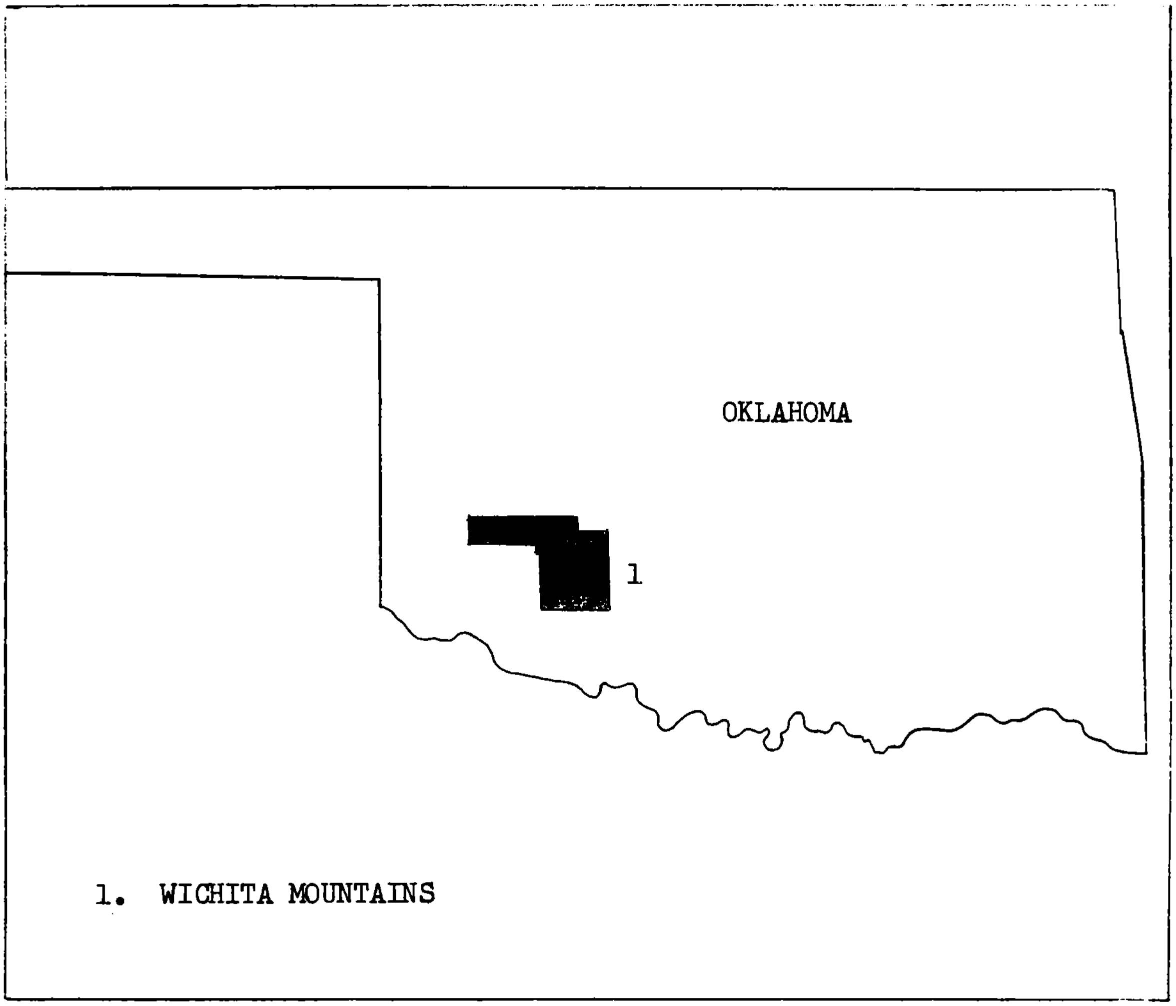


Fig. 56
AIRBORNE RADIOACTIVITY SURVEYS IN OKLAHOMA

occur in northeast trending belts north and south of the mountains. In addition, carnotite mineralization occurs in similar rocks in the valley of the Red River, south of the surveyed area. The purpose of the survey was to obtain information on the distribution of the asphaltite and to make a reconnaissance for possible carnotite deposits. No anomalies were recorded which would indicate carnotite deposition. The flight data have not yet been evaluated with respect to the asphaltite distribution.

Gamma-ray logging studies
by C. M. Bunker

Calibration of the gamma-ray logging equipment was completed and minor mechanical and electronic difficulties were eliminated. A study was made to determine the statistical error and the error created by the instrument resulting from differing response in the ratemeters, tubes and recorders, calibration drift, field abuse, voltage variation, and temperature variation. The standard deviations determined from this study are ± 11 percent, ± 10 percent, and ± 8 percent respectively for range factors 1,000, 10,000, and 100,000 counts per minute. A recent cursory examination of chemical analyses of core and estimations of percent eU_3O_8 from the gamma-ray log of the cored zone indicate that the anticipated error was realistic. The calibrated ratemeters and a calibration chart from which the grade of the radioactive material is estimated were released for service on July 1, 1954.

A jeep-mounted, scintillation logging unit has been field tested and is presently undergoing pre-calibration tests to determine what range factors, time constants, cable speed, and voltage will give the most accurate and useful information. During the next few months the instrument will be calibrated to give grade and thickness information about radioactive strata.

One of the factors required to interpret gamma-ray logs in terms of percent eU_3O_8 is the thickness of the mineralized zone. The thickness must be estimated at some point between the base and the peak of the curve made on the recorder chart. In order to determine the percentage of the peak at which the true thickness is measured 1,100 gamma-ray anomaly curves recorded on an Esterline-Angus strip chart recorder were analyzed. The records were derived from simulated ore for which the true thicknesses were known. A variation of 61 to 91 percent was indicated for a range in thickness of 2.0 to 0.4 feet. To determine an average value which best applies to the deposits of the Colorado Plateau, 675 anomalies from the formation most frequently logged with USGS gamma-ray logging equipment were analyzed. The study indicated that the majority of mineralized zones are from 0.8 to 1.4 feet thick. The thickness measured at seventy percent of peak value is very close to the true value for the 0.8-to-1.4 ft. range.

Gamma-ray and electric log data are now being obtained from closely spaced drill holes in Bull Canyon, Montrose County, Colorado. Isoradioactivity contour maps will be constructed and an attempt will be made to correlate the electric log data with them. Correlations will also be attempted on two other projects from which data were obtained during the past field season.

Physical behavior of radon

by A. S. Rogers

A study is being made of the radon content of well waters in an area of unconsolidated valley fill and lake sediments from North Salt Lake City to Bountiful, Utah. The area under investigation (about 4 by 2 miles) roughly parallels the Wasatch Mountains, which are from 1 to 3 miles east, and includes the north-trending Hot Springs fault. Thermal springs (Becks Hot Springs) occur along the fault about two miles south of the area. The following are the results to date:

1. Beginning at a point about two miles north of Becks Hot Springs, the radon concentration in well water increases from about 350 micromicrocuries per liter to 1400 micromicrocuries per liter within four miles to the north. This is believed to reflect a change in the source

rock for the valley fill sediments. In the southern part of the area, the surface rocks of the adjacent Wasatch Mountains are primarily Tertiary conglomerates which are presumably low in uranium content. Three springs from these conglomerates in the City Creek area contain from 60 to 250 micromicrocuries of radon per liter. In the northern part of the area the source for the sediments is the pre-Cambrian Farmington complex of gneisses, schists and granitic rocks. These rocks are known to contain some uranium mineralization. Springs from the Farmington complex in the Weber River area contain from 380 to 4,430 micromicrocuries of radon per liter.

2. In general, the radon concentration of the ground water does not vary greatly in an east-west direction perpendicular to the mountain front.

3. Little change is noted in radon concentration of the ground waters with changes in depth of the wells.

4. In the southern part of the area, closest to Becks Hot Springs, the radon content of the ground water increases rapidly from a general level of about 350 micromicrocuries per liter to 775 micromicrocuries per liter at the fault. This is believed to be due to an underground mixing of the thermal waters with the ground waters. Becks Hot Springs contains a minimum of 1,350 micromicrocuries of radon per liter.

A brief study of the radon content of plants of the Salt Lake City area was made. The radon was extracted by vigorously boiling the plant material in distilled water and flushing the evolved gas into an evacuated ionization chamber. The following tentative conclusions were reached:

1. The radon content of plants analyzed during September when the weather was hot appeared to be on the order of 50-100 micromicrocuries per liter of plant moisture. The plants used, lilac and pigweed, were assumed to have a moisture content of 80 percent.

2. The radon content of the plants decreased almost to background after the weather turned colder in October, which suggests that the plants do not draw moisture from the soil during cold weather.

3. A large amount of "initial activity" occurred when radon measurements of plants were made (5 to 15 times background). This activity usually has a half-period of about seven minutes and in some instances a series of half-periods were recorded.

Apparently the initial activity is due to heavy ions which are boiled from the plants and cause the ionization chamber to discharge, rather than to the radon contained in the plants. The initial activity due to heavy ions (?) also decreased ($1\frac{1}{2}$ to 2 times background) in plants picked during cold weather, although the plant material picked from the same plant in September still remained active.

Absorption and scattering of gamma radiation
by A. Y. Sakakura

Expressions have been obtained for the radiation intensity above a simulated point uranium source - a slab 40 feet by 40 feet by 6 inches thick located at the Grand Junction airport (Colo.). These expressions have been integrated over various source configurations. The integrations were performed numerically, and the following conclusions were reached:

1. Slope analysis of the anomalies will not yield any unique interpretation.

2. For any anomalies which show flattening at the peak, the boundary, i.e. the extent, of the source is indicated by the one-half intensity points. For anomalies which do not show flattening, the source boundary cannot be determined in such manner.
3. Slab sources greater than 1200 feet in width or finite circular sources greater than 850 feet in radius can be considered infinite in extent.
4. Slab and line sources greater than 1700 feet in length can be considered infinite in length.

A method of interpreting anomalies which yields either grade-area of the source, or grade and area where the anomaly appears on two or more adjoining flight lines, has been developed.

Solution of the gamma-ray transport equation is now under way with the cooperation of J. Heller of the AEC Computing Facility at New York University, using the method of solution developed by Heller for the analogous neutron problem. It is expected that by the summer of 1955 the solutions can be turned out in routine manner. It should be noted that the equation in two media and plane geometry (airborne problem) must be solved for each of the multitudinous lines of the complex uranium spectrum. The solution of the problem eventually will yield the following information: the number of photons of a given energy per unit volume traveling in a given direction at a given distance from the source of a given spectral composition.

Considerable difficulty has been experienced in obtaining reproduceable measurements in the study of gamma-ray distribution in continuous media within cylindrical cavities. No additional measurements will be made until a suitable counter is obtained.

RESOURCE STUDIES

by
W. S. Twenhofel, W. I. Finch, F. W. Osterwald
K. G. Bell and F. W. Stead

Maps showing the location and character of the principal uranium deposits in the United States were completed and approved for publication in the near future. The maps are accompanied by a short text outlining the principal characteristics of the domestic uranium deposits.

Preliminary results of the study of the relationship between major tectonic elements of the eastern part of the Rocky Mountain region and the distribution of known uranium deposits suggest that some deposits may be grouped into three types, according to their structural environments: (1) deposits near axes of major basins (Pumpkin Buttes, Converse Co., and Lost Creek, Sweetwater Co., Wyo.), (2) deposits in folded areas along basin margins, particularly along the flanks of small anticlines (Black Hills, S.D., Gas Hills and Lance Creek, Wyo.), and (3) deposits along or near major northwest-trending faults that cut pre-Cambrian rocks (Ralston Creek, Colo. and Prairie Divide, Colo.).

Literature pertaining to uraniferous deposits associated with hydrocarbons and sedimentary rocks exclusive of sandstones, black shales, and coals occurring in the United States has been reviewed. Several of these deposits in the Rocky Mountain region have been examined. The work to date together with results of investigations carried out in connection with studies of radon and helium, and of mineralogy, petrology and geochemistry of carbonaceous rocks (summarized elsewhere in this report) indicate that large deposits of asphaltite, gilsonite, and similar materials in Colorado, Utah, and New Mexico are not significantly uraniferous. On the other hand, in some localities asphaltic residues consisting principally of disseminated pellets and coatings on joint surfaces are highly uraniferous and uraniferous dead oil stains and asphaltic residues occur with some uranium deposits in the Colorado Plateau area. Investigations are being made to determine the cause for these differences.

As a result of preliminary analytical data on hand pertaining to the natural radioactivity of rocks, it is known that the distribution of natural radioactivity at the surface of the earth ranges widely--i.e., from a few ppm of equivalent uranium to possibly 50 ppm. This so-called "normal" radioactivity is dependent partly upon original distribution of the radioactive elements (the uranium, thorium, and potassium series), and partly upon the present geologic environment. Further analysis of the data should clarify the expectable "normal" variation in radioactivity for a few limited environments such as the Mancos shale, which ranges from 6 ppm to 40 ppm of equivalent uranium where the total radioactivity of 40 ppm consists of 20 ppm caused by the uranium series of elements and 20 ppm caused by the potassium series of elements. It is now apparent that a rather significant variation in total radioactivity of some shales can be attributed to variation in potassium content with no change in uranium content. These studies are being continued.

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