(280)
T67N

TEI-390

GEOLOGIC INVESTIGATIONS OF RADIOACTIVE DEPOSITS

Semiannual Progress Report, June 1 to November 30, 1953

Subject Category, GEOLOGY AND MINERALOGY.

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

December 1953

CONTENTS

ILLUSTRATIONS

TABLES

SUMMARY

Uranium in sandstone-type deposits

Colorado Plateau.--Geologic maps were completed of the Carrizo Mountains in Arizona and New Mexico and the Capitol Reef and Red House Cliffs areas in Utah. Mapping was also done in Utah at White Canyon, Elk Ridge and the San Rafael Swell, and will be continued in 1954. Stratigraphic studies were made of Triassic and Permian formations of southeastern Utah and northeastern Arizona. Except for laboratory work on samples from a hole drilled to obtain core in its original state, no further work was undertaken on stratigraphy of the Jurassic Morrison formation, the field study of which is complete.

Investigation of the horizontal and vertical transmissivity of ground water in sedimentary rocks of the Colorado Plateau shows that the average transmissivity is increased three to five times by fracturing and that a correlation may exist between highly fractured areas and known ore deposits.

For geobotanical research, an experimental garden was established at Santa Fe, N. Mex., to investigate effects on vegetation of soils containing uranium and associated minor elements. Geobotanical sampling, for prospecting, was done in Utah at Deer Flat, Elk Ridge and San Rafael Swell.

Reconnaissance resource appraisal of uranium in Triassic rocks of the Colorado Plateau has pointed out favorable belts for uranium deposition, probably controlled by facies changes or cut offs in the Shinarump.

The new mineral species montroseite, navajoite, and rabbittite were established and two other new, unnamed species were identified, a sodium vanadate and a potassium uranyl arsenate.

Geophysical investigations by gravity and magnetic methods are being made of the entire Plateau region. Experimental investigations of selected areas were made by seismic refraction, magnetic, electrical resistivity, and self potential methods to determine the applicability of the various methods in guiding exploration. Electric logs of drill holes give some promise of usefulness in delineating ground favorable for uranium deposition.

Areas outside of Colorado Plateau.--Uranium was recognized in Cretaceous and Eocene sediments in the Gas Hills area, central Wyoming, in sandstone and carbonaceous shale. The greenish-yellow mineral is tentatively identified as uranospinite. Some samples contain 0.041 to 1.87 percent U.

Geologic mapping in the Powder River Basin, where uranium mineralization occurs in small concretionary masses and as disseminations in sandstone, has suggested several tentative guides to hidden uranium deposits.

Uranophane is the principal uranium mineral in sandstone deposits in the Browns Park formation of the Poison Basin area near Baggs, Carbon County, Wyoming. The occurrences are distributed over a distance of at least a mile.

Approximately 68 square miles have been mapped in the southern Black Hills, South Dakota, near Edgemont. The greatest density of uranium occurrences appears to be marginal to the steepest dips of ore-bearing beds and the larger deposits are localized in alternating sandstones, mudstones, and siltstones. The localization of carnotite appears to depend largely on structure and the variation between permeable and impermeable lithologies of the host rocks.

Uranium in veins, igneous rocks, and related deposits

Pitchblende and secondary uranium minerals were discovered in the Eureka-Nigger Hill area of the Georgetown-Central City district of the Colorado Front Range, Colo. Occurrences at the Two Sisters and R.H.D. mines are in part of ore grade. The mineralization occurs in two and possibly three vein sets. In the Idaho Springs district uranium has been found in pyrite-quartz veins.

To date about 28 square miles of surface mapping and 85,000 linear feet of underground mapping has been done in the various mining districts in the Colorado Front Range.

Wall-rock alteration is similar to that found elsewhere in the Front Range with successive layers of silicified, sericitic and argillic material between the vein and fresh rock. Argillic alteration in this area appears more widespread than was previously reported.

Detailed mineralogic and petrographic studies of pitchblende-coffinite ore from the Copper King mine were made. It was impossible to separate a pure sample of coffinite for analysis.

Uranium in carbonaceous rocks

Coal and lignite.--Ash of coal from the waste dump of the Southern Utah Power Company's plant near Cedar City, Utah, was found to contain 0.01 percent eU. The coal was mined at the Webster mine near Cedar City and two other mines at the same horizon; its ash content is 9 percent.

In the Ekalaka lignite field, Carter County, Mont., a bed of weathered lignite as much as 8 feet thick contains 33.8 percent ash and 0.014 percent U in the ash. About 70 square miles of this field was mapped on photographs. In the HT Butte and Chalky Buttes area, Slope County, N. Dak., uranium occurs in the Slide Butte and Chalky Buttes beds in the Fort Union formation; the area underlain by the radioactive lignite beds is about 9 square miles. Uraniferous lignite was also found in Bullion Butte and Sentinel Butte, Slope and Golden Valley Counties, N. Dak.

Drilling in the Mendenhall area, Slim Buttes, Harding County, S. Dak., was completed in June 1953. Preliminary estimates indicate that more than 4,000 acres in the area is underlain by radioactive lignite having a mineralized thickness of more than 4 feet. The mineralization occurs in three beds: the Mendenhall rider, the Mendenhall, and the Olesrud.

Core drilling in the Red Desert area, Sweetwater County, Wyo., was completed in November 1953. A total of 60 core holes aggregating 12,677 feet were drilled, as well as one 8-inch core hole. Also, 142 power-auger holes were completed. On the basis of radioactivity determinations, it appears that locally coal 6.5 feet thick contains 0.007 percent U and 0.05 percent U in the ash, though the average uranium content for the field is about 0.003 percent or less. The distribution of uranium in the coal beds in the Red Desert appears to be governed largely by the permeability of the overlying rocks; it increases from west to east as the overlying rocks become coarser-grained and more permeable.

Black shales.--The drilling program in the Chattanooga shale completed in November, consisted of 36 closely spaced holes in the Youngs Bend area near Smithville, DeKalb County, Tenn., and 28 widely spaced holes in the Northern Highland Rim, the Eastern Highland Rim, and Walden Ridge, Tennessee, and Blount County, northern Alabama.

A small sample of organic stringer from one of the shale cores contained only 1.27 percent ash, which analyzed 2.58 percent U and 4 percent germanium. A report describing this newly observed occurrence of germanium and association of germanium and uranium is in preparation.

Based on field observations that the uranium content of black shale might be a function of color, a study was made of the correlation between uranium content, radioactivity, and the reciprocal of reflected light in microamperes; the density of the reflected light was measured in a reflection fluorimeter funnelling white light onto the surface of shale samples. The correlations obtained in the work to date are good. If further experiments show that the method is feasible, it may provide a satisfactory rapid method for the determination of uranium in shales.

Uranium in phosphates

The geologic drilling program in the land-pebble phosphate district, Florida, was completed. A total of 115 holes aggregating 6,796 feet have been logged, sampled, and a gamma ray log taken in each.

Reconnaissance for uranium in the United States

At the Phillips pyrite mine, Putnam County, New York, uraninite is associated with magnetite, hornblende gneiss, and possibly a sulfide-bearing shear zone in diorite. If the uranium is coextensive with the magnetite-bearing rock, there may be a large tonnage of uranium.

Analytical service and research on methods

During the reporting period 13,786 chemical determinations for uranium, 15,056 other chemical determinations, 169,049 spectrographic determinations, and 13,223 radioactivity determinations were completed by the laboratory.

A technique for additional refinement of semi-quantitative data derived from spectrographic determinations has been devised. The method reported results for sixty or more elements to narrower ranges of concentration than formerly, i.e., o.x- for 0.1% to 0.215%, o.x for 0.215 to 0.464% and o.x+ for 0.464 to 1.0%, and similarly for other orders of magnitude.

A new fluorimeter has been developed and constructed that incorporates the use of three electronic tubes in the circuit rather than a single photomultiplier tube commonly used in instruments of this type.

Geochemical and petrological research on basic principles

In connection with studies of the distribution of uranium in igneous complexes the zircon-age method has been refined and perfected and extended to include other accessories such as xenotime and monazite.

The isotopic composition of meteoritic lead has been successfully determined and is found to be very different from every terrestrial lead so far tested. Results suggest that if the earth is 4.5 billion years old, it may have originally contained lead of such composition.

Development and maintenance of radiation detection equipment

A prototype model of a new portable scintillation counter has been designed and built. It is a total intensity type meter, weighs 3.5 lbs., has a displacement volume of 71.5 cubic inches and a battery life of 180 hours.

URANIUM IN SANDSTONE-TYPE DEPOSITS

Colorado Plateau geologic studies

Regional geologic mapping

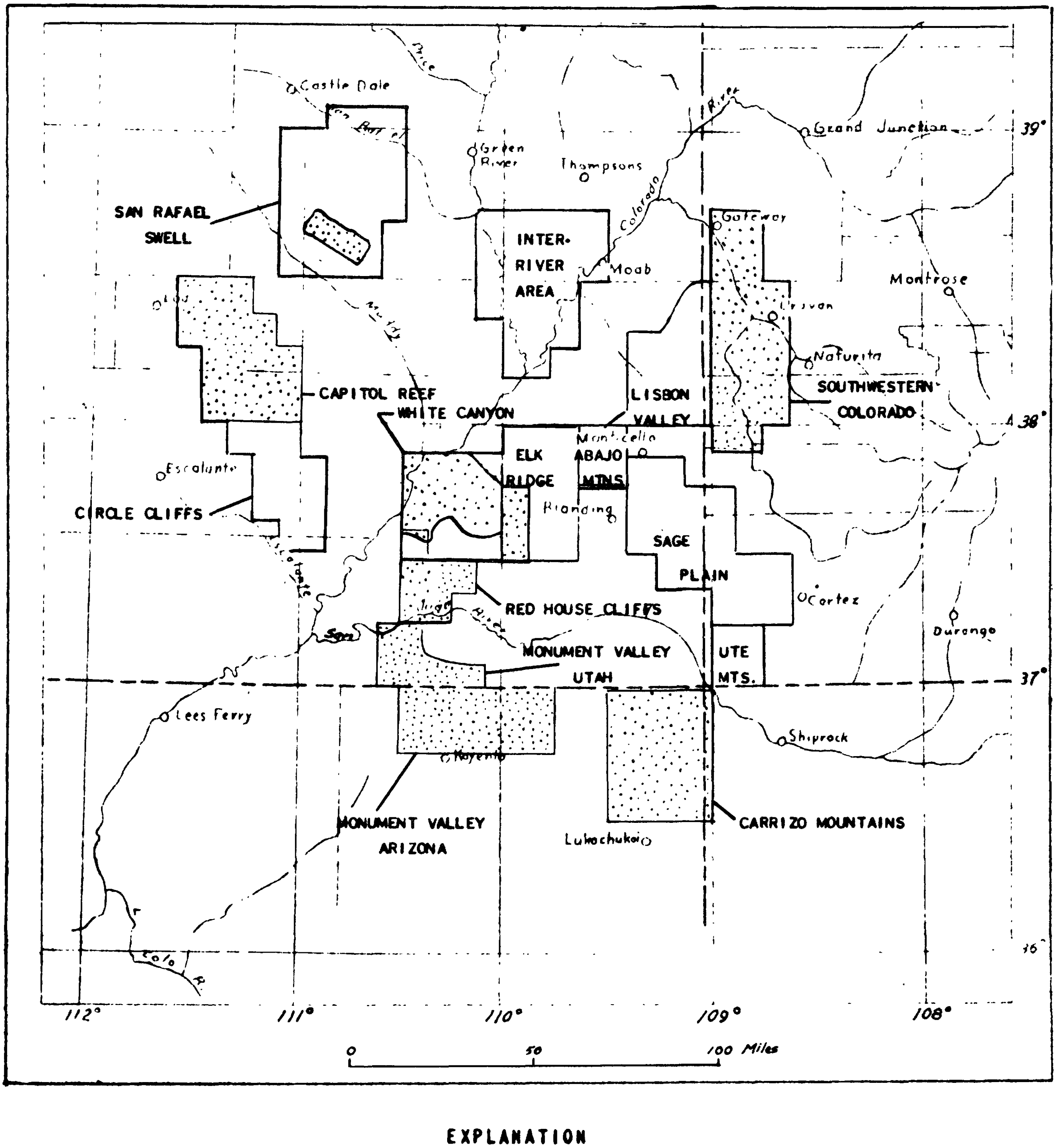
The geologic mapping projects are aimed at appraising the ore deposits in the main uranium-bearing formations of the Colorado Plateau region, the Morrison formation of Jurassic age and the Shinarump conglomerate and adjacent formations of Triassic age. The mapping falls into two categories: strip mapping projects and quadrangle mapping projects. Strip mapping involves the detailed study and mapping of only the ore-bearing beds and adjacent strata; it is undertaken only in those regions where an adequate geologic map already exists. Quadrangle mapping involves not only the detailed study and mapping of the ore-bearing beds and adjacent strata but also the extension of geologic mapping to the boundaries of quadrangles as a step toward complete understanding of the geology of the region.

Field work has been completed prior to this report period for the following projects, and final reports are being processed: Southwestern Colorado area quadrangle mapping project; Monument Valley area, Ariz., quadrangle mapping project; and Monument Valley area, Utah, strip mapping project (fig. 1). The incomplete results of these projects have been reported in TEI-330.

Field work has been completed during this report period for the following projects: Red House Cliffs area, Utah, quadrangle mapping project; Capitol Reef area, Utah, quadrangle mapping project; and the Carrizo Mountains area, Ariz.-N. Mex., quadrangle mapping project (fig. 1).

U.S. DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

COLORADO PLATEAU GEOLOGIC STUDIES
SEMIANNUAL REPORT, NOVEMBER 1953



EXPLANATION

AREA TO BE MAPPED

AREA OF MAPPING COMPLETED NOVEMBER 1953

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

Field work has been continued for the White Canyon area, Utah, quadrangle mapping project and field work began for the San Rafael Swell area, Utah, strip mapping project and the Elk Ridge area, Utah, quadrangle mapping project (fig. 1).

During the next report period field work is tentatively planned for the following: Lisbon Valley area, Utah-Colo., quadrangle mapping project; Abajo Mountains area, Utah, quadrangle mapping project; Inter-River area, Utah, strip mapping project; Circle Cliffs area, Utah, quadrangle mapping project; and Sage Plain area, Utah-Colo., quadrangle mapping project. A TE report summarizing results of geologic reconnaissance of the Ute Mountains area, Colo., prepared by the distribution of elements project, will be transmitted in the next report period; a quadrangle mapping project involving detailed geologic work is planned in the near future to supplement the reconnaissance study.

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

Geologic mapping of the Carrizo Mountains area in northeastern Arizona and northwestern New Mexico (fig. 1) was undertaken to provide detailed information on the geologic occurrence of uranium deposits in the 30-minute quadrangle surrounding the Carrizo Mountains. Mapping of about 900 square miles was completed by September 1951, and the field work was recessed. During the recess, a preliminary appraisal of the uranium resources of the area was prepared (TEM-300, May 1952), and preliminary drafts of the geologic map were transmitted (TEM-415-430, July-August 1952). The geologic map and accompanying text and stratigraphic sections were also prepared for publication in the Oil and Gas Investigations Map series of the Geological Survey.

During this report period the laccolithic complex of the Carrizo Mountains was mapped. Except for final checking of the geologic map field work has been completed.

Sedimentary rocks exposed in the area aggregate nearly 5,000 feet in thickness and range in age from Permian (Cutler formation) to Pliocene (?) (Chuska sandstone). The following variations from the general stratigraphy of the Colorado Plateau region are notable. The Moenkopi formation (Triassic) is absent. The Shinarump conglomerate (Triassic) is thin and exposed only locally on the southwest flanks of the mountains. The Kayenta formation and Navajo sandstone (Jurassic?) and the Carmel formation (Jurassic) thin and disappear southeastward across the area, whereas the Todilto limestone (Jurassic) thins and disappears northwestward. Four members of the Morrison formation (Jurassic) are recognized: in ascending order, the Salt Wash, Recapture, Westwater Canyon, and Brushy Basin members.

These sedimentary rocks have been folded and truncated, and are overlain in places by the flat-lying Chuska sandstone (Pliocene?) and associated basalt flows. They have been intruded by diorite sills and laccoliths in the Carrizo Mountains and also around the margin of the Carrizo Mountains by minette plugs and dikes younger than the diorite and younger than the Chuska sandstone. It was thought that the mapping of the Carrizo Mountains might produce direct evidence of the age of the diorite of the laccoliths, but as no Chuska sandstone or other Cenozoic rocks occur in the mountains, the diorite can only be dated as older than the minette (Pliocene?) and younger than the Mancos shale (Late Cretaceous).

The uranium deposits are of the carnotite type and are contained in the Salt Wash member of the Morrison formation. The stratigraphic position of the ore ranges from the middle of the Salt Wash member east and south of the mountains to the base of the Salt Wash member northwest of the mountains. The position of the ore may be controlled by thickness or composition of the member or by some factor superposed upon it, such as a former water table. The carnotite deposits adjacent to diorite intrusives occur beneath the igneous rocks and do not appear to be related to the igneous rocks. No direct evidence of the relative age of the uranium deposits and the igneous rocks was found during field work. Tentatively, because of the frequency and distribution of the ore deposits with respect to the igneous rocks of the intrusive masses, the ore deposits are interpreted as older than the igneous rocks.

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

Geologic mapping of the Red House Cliffs area, southwestern San Juan County, Utah, (fig. 1) was completed during this report period. About 40 square miles were mapped since June 1953, and the Shinarump conglomerate was examined along all accessible exposures.

No known deposit of uranium occurs in the Red House Cliffs area. On the basis of empirical guides developed in the adjacent Monument Valley and White Canyon areas, Utah, the Shinarump conglomerate of the Red House Cliffs area is apparently a favorable host rock for uranium deposits. However, the Shinarump conglomerate of the Monument Valley area extends northward only about 3 miles into the Red House Cliffs area where it pinches out, and the Shinarump conglomerate of the White Canyon area pinches out north of the north boundary of the Red House Cliffs area.

The Shinarump conglomerate which extends into the area from Monument Valley fills several channel-scours at its base. Carbonaceous material, which is considered favorable for ore, is abundant in the channel sediments. These channels, where near a margin of deposition of Shinarump conglomerate, are thought to be favorable for the accumulation of uranium deposits because they contain uranium deposits in adjacent areas. The reason for the association of uranium deposits with channels and a margin of deposition of Shinarump conglomerate is not known, but the association does furnish an empirical guide to uranium deposits. Geologic evidence indicates that about 15 square miles in the southwest part of the Red House Cliffs area, or only about 5 percent of the mapped area, is underlain by Shinarump which locally contains channels near a margin of deposition of Shinarump conglomerate. Possibly some concealed uranium deposits occur in these channels.

A final report summarizing the results of geologic study of the Red House Cliffs area is in preparation.

<u>White Canyon area, Utah, quadrangle mapping project</u>, by A. F. Trites, Jr.

The White Canyon area is on the west flank of the Monument upwarp in the west central part of San Juan County, Utah. During this report period the geology of about 100 square miles in Red Canyon and 100 square miles in White Canyon were mapped on a scale of 1:48,000. Detailed geologic studies were continued at the Jomac claim. A drilling project based on recommendations made by personnel of the White Canyon area mapping project was begun on Deer Flat; the preliminary results of this exploration project are reported separately in the section on Colorado Plateau Exploration.

Geologic studies in the White Canyon area during the 1953 field season indicate that much of Red Canyon is unfavorable for the occurrence of significant deposits of uranium in the Shinarump conglomerate. This conglomerate is present in most of the middle part of Red Canyon and is locally as thick as 40 feet; it is either missing or extremely thin in the lower part of Red Canyon.

About 15 Shinarump-filled channels in the Moenkopi formation are present in the area and range from 40 to 600 feet wide and from 4 to 25 feet deep. Abnormal radioactivity was found in many of these channels, but uranium-bearing rock containing more than 0.10 percent U_3O_8 was found in only one channel. The uranium occurs in carbonaceous sandstones in the lower part of this channel, associated with secondary copper minerals and minor sulfide minerals. Abnormal radioactivity was also found in carbonaceous sandstone lenses and in coal seams in the lower member of the Chinle formation, but these deposits are believed to be small and of low grade.

Detailed studies at the Jomac mine show that the uranium is concentrated in pieces of coal in a basal sandstone bed of the Shinarump conglomerate. The coal accumulated in basin-like depressions that have been cut in siltstone beds of the Moenkopi formation and Shinarump conglomerate, and filled by silty sandstone of the Shinarump conglomerate. The uranium occurs in torbernite, autunite, and possibly as an organic uraniferous compound.

The following reports are in preparation: "Uranium deposits at the North Point claim, White Canyon area, San Juan County, Utah," by A. F. Trites, Jr.; "Progress report on geologic studies in the White Canyon area, San Juan County, Utah, 1953," by A. F. Trites, Jr., T. L. Finnell, and R. E. Thaden; and "Preliminary report on Happy Jack mine, San Juan County, Utah," by A. F. Trites, Jr. and R. T. Chew, III.

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

Geologic mapping in the Capitol Reef area, Wayne and Garfield Counties, Utah (fig. 1), was completed during this report period. About 550 square miles were mapped during the 1953 field season, and the Shinarump conglomerate was examined at all accessible exposures.

Exposed sedimentary rocks range from the Permian Coconino sandstone to beds of a possible Lower Tertiary age and have an aggregate thickness of more than 5,000 feet. Volcanic rocks crop out in the western part of the area. Structural features include the northwestward extension of the Waterpocket Fold, the Teasdale anticline, and numerous faults.

Radioactive rock has been found in the Moenkopi formation, the Shinarump conglomerate, the Chinle formation, the Curtis formation, and the Salt Wash member of the Morrison formation. Most radioactive rock is in the Shinarump conglomerate in a clay and sandstone layer at the base of the formation where Shinarump beds have filled channels cut into the underlying Moenkopi formation. Uranium minerals identified from the area include betazippeite, metatorbernite, johannite, and pitchblende disseminated in carbonaceous material from the Oyler mine in the Shinarump conglomerate. Secondary copper minerals, minute grains of chalcopyrite, and pyrite, gypsum, and in places iron and manganese stain are associated with the uranium minerals.

Uraniferous rock in the Moenkopi formation occurs at the base of a cross-bedded sandstone overlying a red siltstone about 400 feet below the top of the formation. Although the uranium minerals from this locality have not been identified, a one-foot channel sample contained 0.41 percent uranium.

No uranium deposits that appear to be significant economically were found in the Chinle formation. Abnormally radioactive material occurs in widely scattered fragments of silicified wood, in scarce bone fragments, and in one sandstone lens in the southern part of the area.

The uranium deposits at the Billy's Dream claim in the Salt Wash member of the Morrison formation are in a sandstone and conglomerate lens near the top of the member. Carnotite occurs along cross-bedding in the sandstone, and along cross-bedding and as pebble coatings in the conglomerate.

At the base of the Curtis formation in the northeast part of the area carbonaceous fragments 1 to 3 inches long and about 1 inch thick show abnormal radioactivity and associated copper stains. These spots are scattered and appear to have no economic significance at present.

During this period a report on a special phase of work in the Capitol Reef area was prepared for transmittal as TEM-643, "Preliminary geochemical studies in the Capitol Reef area, Wayne County, Utah," by Lyman C. Huff.

Studies during the next report period will be aimed at the preparation of a final report. About two man-months will be spent in the field during the late spring of 1954 to check results of the winter work and to examine any new claims or developments in the area.

Elk Ridge area, Utah, quadrangle mapping project, by R. Q. Lewis, Sr.

The Elk Ridge area is on the crest of the Monument upwarp in the central part of San Juan County, Utah. About 150 linear miles of the Shinarump-Moenkopi contact and of the Chinle-Moenkopi contact where the Shinarump is missing were examined during this report period. The geology of two $7\frac{1}{2}$-minute quadrangles, covering about 120 square miles, was mapped.

Exposed sedimentary rocks range from the Rico formation of Permian age to the Morrison formation of Jurassic age and have an aggregate thickness of more than 5,000 feet.

The known uranium deposits are confined to rocks of Triassic age. Most of the deposits are in the Shinarump conglomerate which crops out as discontinuous lenses at the base of the Chinle formation. Two deposits in other formations were examined. Uranium ore at the East Woodenshoe claim in Woodenshoe Canyon is in a sandstone lens about 2 feet thick in the lower part of the Chinle formation, about 30 feet above the Shinarump conglomerate. At the Notch No. 5 claim on the south side of Notch Canyon uranium ore is in the Moenkopi formation about 40 feet below the Shinarump conglomerate. These deposits are significant under present economic conditions and indicate the possibility of finding additional ore in the Moenkopi and Chinle formations in the Elk Ridge area.

Two reports giving results of work to date are in preparation. TEM-713 discusses the geology of Burch Canyon, which appears to be a favorable locality for exploration for uranium deposits. TEM-714, a progress report, discusses the preliminary results of geologic study in the Elk Ridge area, Utah. Field work will be resumed in June 1954.

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

Strip mapping of the ore-bearing Shinarump (?) conglomerate and associated formations began in the San Rafael Swell, Emery County, Utah (fig. 1), in July 1953. About 40 linear miles, or about 10 percent, of the Shinarump (?) conglomerate outcrop were mapped. Reconnaissance studies were made around the remainder of the Swell. Mines, near Temple Mountain, at AEC calyx holes Nos. 4, 5, 6, 8, and 9, and Rex mine No. 1 were mapped at a scale of 1 inch equals 50 feet.

The Shinarump (?) conglomerate ranges from 30 to 175 feet in thickness and consists of interfingering lenticular beds of conglomerate, sandstone, and mudstone. Fragments of charred and silicified wood are scattered irregularly through the sediments. The Shinarump conglomerate as previously defined in the Swell may not correlate with the Shinarump conglomerate of the type area. The Shinarump (?) is the principal host rock of minable uranium deposits, although the Wingate sandstone and Moenkopi formation also contain uranium minerals at Temple Mountain.

The principal producing area is at Temple Mountain where the uranium ore is in the basal one-third of the Shinarump (?). The ore, tentatively identified as the black uranium mineral coffinite, appears to be in association with asphalt-like material; away from Temple Mountain ore is less commonly associated with the asphaltic material and secondary copper minerals and carbonaceous matter are important either as localizing agents or associates with the uranium minerals.

Geologic associations that may serve as guides to ore include abnormally high radioactivity, observable uranium and vanadium minerals (Rex mines), asphaltic material (Temple Mtn.), carbonized wood, thickening of the basal sandstone lens of the Shinarump conglomerate (?), secondary copper minerals (Green Vein Mesa), fracturing (Rex mines), and bleaching of rocks by possible hydrothermal solutions (Temple Mtn.). Studies to date indicate that the uranium minerals have gone through one or more periods of redeposition and that the origin of the ores is complex.

<u>Comb Ridge area, Utah, quadrangle mapping project</u>, by J. D. Sears

During this report period the Geological Survey completed a geologic mapping project along Comb Ridge, San Juan County, Utah, under the direction of J. D. Sears and financed entirely by Geological Survey funds. The main purpose of the project was to train younger Survey geologists in mapping techniques. Two $7\frac{1}{2}$-minute quadrangles along Comb Ridge completed the mapping of Triassic rocks north of the San Juan River and south of the Elk Ridge, Utah, mapping project. Reports for the TE series will be prepared by the Comb Ridge project and will afford an appraisal of uranium possibilities on the east margin of the Monument Valley upwarp.

Photogeologic mapping

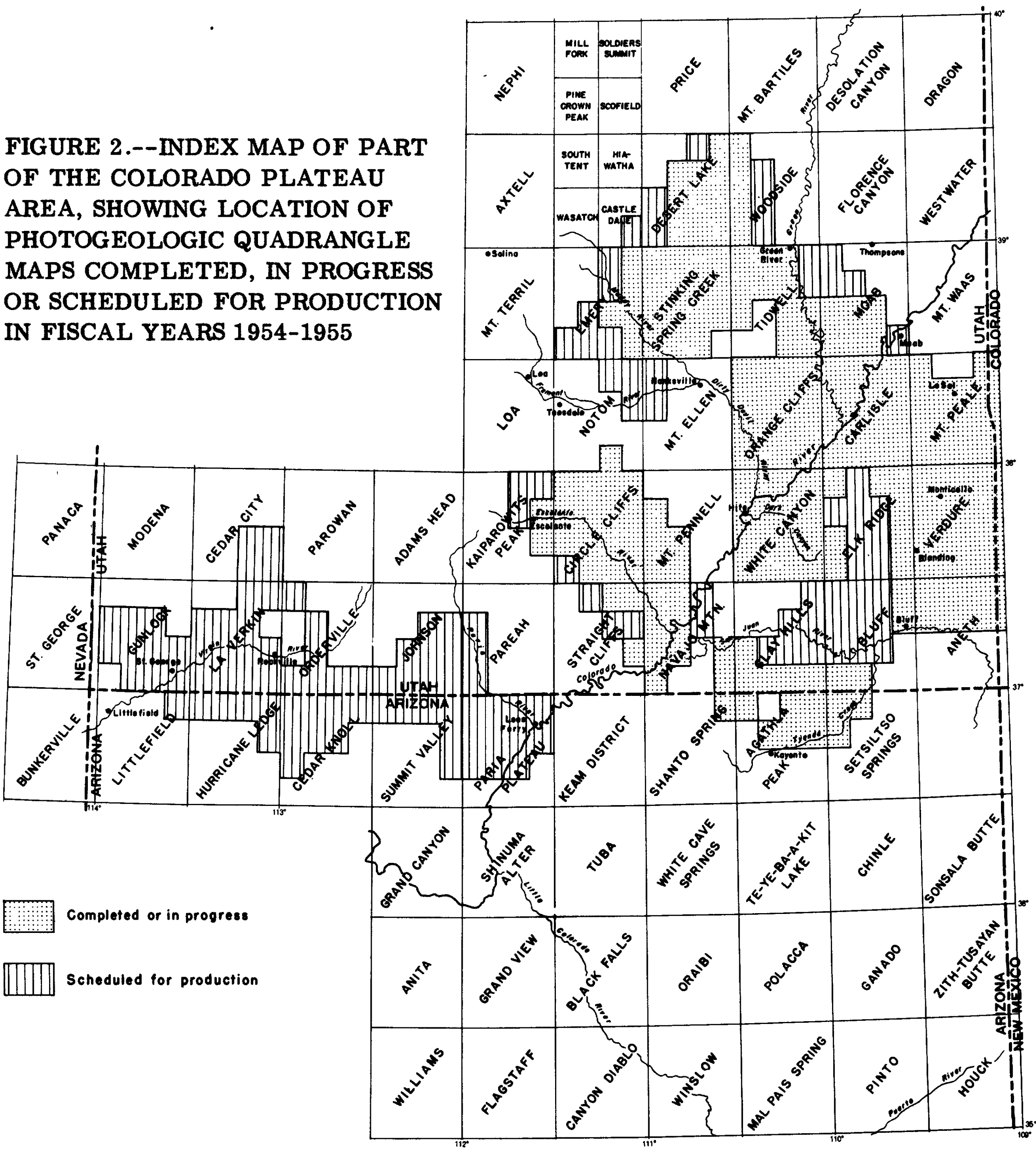
The photogeologic mapping program is designed to provide regional geologic maps of specified areas in Utah and Arizona to serve the needs of the Atomic Energy Commission and the public until more detailed ground surveys can be made.

Since the beginning of the photogeology project in the winter of 1951-52, approximately 11,940 square miles of photogeologic mapping has been completed or is in the latter stages of production. The areas completed, in production, or scheduled are shown on the map (fig. 2).

In addition to normal photogeologic mapping program, special photogeologic maps and studies (e.g. isopachous maps) of certain areas designated by the Grand Junction office of the United States Geological Survey are being prepared.

Continuing efforts to increase the accuracy of the photogeologic maps produced for this program are being made by greater use of stereo plotting equipment and techniques.

FIGURE 2.--INDEX MAP OF PART OF THE COLORADO PLATEAU AREA, SHOWING LOCATION OF PHOTOGEOLOGIC QUADRANGLE MAPS COMPLETED, IN PROGRESS OR SCHEDULED FOR PRODUCTION IN FISCAL YEARS 1954-1955



Stratigraphic studies
by G. A. Williams

Morrison formation

Field studies of the Morrison formation have been completed except for spot checking of critical areas. Sedimentary petrology studies, continued through this report period, are near completion. Reports presenting results of studies of sedimentary structures, pebbles, and sedimentary petrology are in preparation. Three TE reports, "Lithofacies of the Salt Wash member of the Morrison formation," by T. E. Mullens and V. L. Freeman; "Testing of graphical methods of grain size analysis of sandstone and siltstone," by R. A. Cadigan; and "A method of making a quantitative estimate of silicified tuff in sandstone through the use of benzidine," by R. A. Cadigan, will be transmitted in the next report period. A comprehensive report summarizing the results of stratigraphic studies of the Morrison formation is in preparation.

Work on the Morrison formation during the report period has been confined mostly to the grain-size analysis of samples from a test hole drilled in connection with the original-state core study. Textural properties of 21 samples selected from above, within, and below a mineralized horizon were correlated mathematically with each other and with the measured dry air permeability. Study and evaluation of the correlations yield general conclusions regarding textural relationships including the effect of some properties of sandstones and siltstones on air permeability and on the deposition of calcite and similarly soluble ore minerals.

Dry air permeability in sandstone and siltstone is closely related to the properties of the grain size distribution and the amount of cement.

Specifically, average grain size and peakedness of the distribution curve (kurtosis) are of primary importance; symmetry of the distribution (skewness) is of secondary importance (negative skewness favors permeability), and sorting as measured by the phi standard deviation is of minor importance -- poor sorting tends to decrease permeability.

Calcite cement and other acid and water soluble minerals, including some ore minerals, are more often found in greater quantities in poorly sorted sediments with an excess of fine materials than in well-sorted sediments with symmetrical grain-size distribution or in poorly sorted sediments with an excess of coarse particles.

The results of the mathematical tests favor the possibility that a simple formula may be derived for translating the thousand grain-size analyses on hand into estimated permeability data.

Triassic and related formations

Field work on the stratigraphy of the Triassic and related formations during this report period was centered in southeastern Utah, but small amounts of work were done in south-central and east-central Utah and northeastern Arizona.

The lithology of the Permian Cutler formation changes abruptly in east-central Utah. Between the Dirty Devil River and the Green River the Cutler is dominantly composed of clean light-colored sandstone and is probably a wind-laid deposit. Between the Green River and the Colorado River, the Cutler is dominantly composed of reddish siltstone and fine- to medium-grained arkose and is probably a stream-laid deposit. East of Moab, Utah, the Cutler is dominantly composed of coarse-grained conglomeratic arkose and is probably a stream-laid deposit.

The Hoskinnini tongue of the Cutler formation is an exceptionally consistent marker unit among other highly variable units. The distinctive lithology of the Hoskinnini may be traced from Monument Valley, Utah, to the Utah-Colorado line east of Moab; it pinches out abruptly on the west along a northerly trending line through the middle of White Canyon and through a point about 20 miles upstream from the mouth of the Green River. The eastern limits of the Hoskinnini are not known.

The Lower Triassic Moenkopi formation thins eastward from the San Rafael Swell and Capitol Reef areas. The Sinbad limestone member of the Moenkopi, which is well-developed in the San Rafael Swell and Capitol Reef, thins eastward and is represented by several thin, possibly discontinuous, limestone beds in the area between the Dirty Devil and Green Rivers. The Moenkopi is composed dominantly of siltstone or very fine-grained sandstone that probably was deposited in or bordering a sea that spread eastward across Utah.

The Upper Triassic Shinarump conglomerate of Monument Valley, Utah-Ariz., is not the same as the so-called Shinarump conglomerate of east-central Utah. In Monument Valley, the Shinarump conglomerate is a well-developed coarse-grained sandstone that probably correlates with the Shinarump of the type locality near Kanab, Utah; in the White Canyon area the Shinarump thins and pinches out irregularly. Along the Dirty Devil River and between the Dirty Devil and Green Rivers, the so-called Shinarump unit is composed of fine- to very fine-grained sandstone and siltstone and correlates with part of the "D" member of the Chinle formation; this unit thins and pinches out northward. Between the Green and Colorado Rivers the so-called Shinarump unit is composed of fine- to medium-grained sandstone; it is the uppermost sandstone unit of the "D" member of the Chinle formation, and is provisionally named the Mossback sandstone; this unit thins and pinches out north of Moab, Utah.

The Mossback sandstone can be traced southward from near Moab to the White Canyon area where the unit forms conspicuous outcrops about 200 feet above the Shinarump conglomerate. The so-called Shinarump conglomerate of the San Rafael Swell is probably the Mossback sandstone.

The Shinarump conglomerate is a coarse-grained, commonly conglomeratic sandstone whereas the Mossback is a fine- to medium-grained, commonly conglomeratic, sandstone. The pebbles in the Shinarump are predominantly light-colored quartz, chert, and quartzite, whereas the pebbles in the Mossback are predominantly limestone and siltstone with abundant dark-colored quartzite and common quartz and chert.

The Shinarump contains medium-scale trough cross-stratification, whereas the Mossback, in addition to medium-scale trough cross-stratification, commonly contains horizontal and ripple stratification. Studies of cross-strata in the Shinarump suggest that in general the streams flowed northwest; studies of cross-strata in the Mossback suggest that in general the streams flowed west-northwest. These differences suggest separate source areas for the Shinarump and the Mossback.

The Upper Triassic Chinle formation is divided into several members and units, some of which are local, whereas others are found throughout northern Arizona and southern Utah. The Chinle is composed dominantly of mudstone and arkosic sandstone. The Chinle is probably mostly a stream and flood-plain deposit that had several source areas of which southern Arizona and New Mexico seem to be the most important.

The uranium deposits that were once thought to occur in a single unit, the Shinarump conglomerate, are now known to occur in three different units. In Monument Valley, White Canyon, Circle Cliffs, and Capitol Reef the deposits occur in the Shinarump conglomerate. In the area between Dirty Devil and Green Rivers and southern part of the San Rafael Swell they occur in sandstone of the "D" member below the Mossback sandstone. In the northern part of the San Rafael Swell, in the area between the Green and Colorado Rivers, and possibly in Big Indian Wash the deposits occur in the Mossback sandstone.

The deposits in each of the three Upper Triassic units occur dominantly in an interval immediately above to 50 feet above the top of the Moenkopi formation. Deposits in the Mossback sandstone have been found only where the Mossback lies within 50 feet of the top of the Moenkopi formation.

In each of the three units the deposits occur in broad northwest-southeast trending belts near the northern limit of the unit. Possibly these belts are related to permeability traps in areas where the units are discontinuous.

The uranium deposits in the Cutler formation apparently occur only in the arkosic sandstone facies. The search for deposits in the Cutler thus probably can be concentrated on this arkosic facies which is confined to extreme east-central Utah and west-central and south-central Colorado.

Ground-water studies
by D. A. Jobin

In the previous report period work began on the problem of determining the horizontal and vertical transmissivity relationships of the exposed sedimentary rocks of the Colorado Plateau. These rocks were sampled in eight areas: Grand Junction, Colo.; Uravan, Colo.; McElmo Canyon, Colo.; Monument Valley-Black Mesa, Ariz.; Comb Ridge, Utah; Circle Cliffs, Utah; San Rafael Swell, Utah; and the Moab area, Utah.

Laboratory work during the period, although largely taken up by assembling and testing new equipment and standardizing procedures, included also determining the variations in permeability in one area, Grand Junction, Colo. Grain-size analysis of the same samples is also nearing completion.

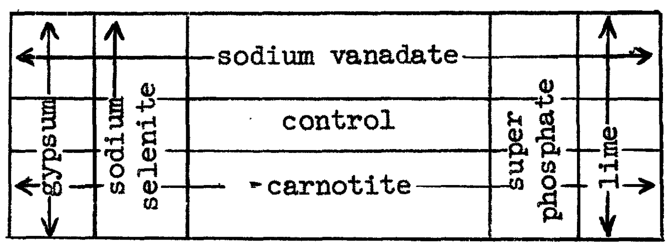
An evaluation of the effect of the present system of fractures on the transmissivity of the Salt Wash member of the Morrison formation has been accomplished by use of the water consumption data from the drilling records of four representative drilling projects: the Yellow Cat area, Grand County, Utah; Outlaw Mesa, Mesa County, Colo.; Atkinson Mesa, Montrose County, Colo.; and the Spud Patch area, San Miguel County, Colo. By computing the mean transmissive rates for unfractured rock for each area and comparing this value to the value determined by using all the data, a semi-quantitative estimate of the minimum increase in transmissivity due to fractures was obtained. In the areas studied the average transmissivity of the rocks has apparently been increased from three to five times by the presence of fractures. Maps were prepared contouring the total transmissivity of representative bore holes for these same areas. Preliminary results suggest that there may be a possible correlation of the highly fractured, i.e. highly transmissive, areas with known ore deposits.

Plans for the regional transmissivity project for the next report period include completing the laboratory measurements on the samples already collected, and summarizing the data in a preliminary report.

Geobotanical studies

Geobotanical research, by H. L. Cannon

Geobotanical research during the report period was largely directed toward an experimental investigation of indicator and absorber plants in relation to uranium and other elements in the environment of an ore deposit. An experimental desert garden was established in Santa Fe County, N. Mex., under conditions of soil, temperature, and moisture typical of the Colorado Plateau. Selected desert plants were planted in plots containing excess amounts of several basic nutrient elements in combination with carnotite. The pattern of plot arrangement is shown:



Ten species of plants germinated with great variation in these plots; five were grown to maturity and five perennials acquired first year growth. Six additional species were added in a fall planting. Growth habits were studied at weekly intervals, and variations were recorded. A marked increase in germination, growth, and time of flowering was observed in certain species grown in carnotite plots. Stanleya and Cleome, however, were inhibited by additions of carnotite although very tolerant of high selenium and sulfur soils. Grindelia was found to be highly tolerant of carnotite soils, and will even germinate and grow rapidly in soils containing one-half pure carnotite. The amounts of uranium absorbed by these plants will be of interest.

A cooperative program of chemical research on the plot soils and plant samples grown in the plots is planned and is expected to answer the following questions:

In what form are uranium and vanadium absorbed by plants?

How and where are uranium and vanadium stored in the plant?

What is the relation of the uranium and vanadium content to the dry weight and ash figures in absorbed plants versus indicator plants?

What controls the distribution of plants known to act as indicators of carnotite ores?

An initial number of analyses will be run this winter. The experiments are planned to extend over a 2-3 year period in order to bring to maturity perennial plants and shrubs known to be useful in geobotanical prospecting.

Black and white photographs of indicator plants were taken during the 1953 field season to be used as illustrations in a handbook for geobotanical prospecting. Compilation of the descriptive data is continuing.

Geobotanical prospecting

The absorber plant method of geobotanical prospecting, by A. J. Froelich

The absorber plant method of geobotanical prospecting utilizes uranium-assay information based on the absorption and accumulation of anomalous amounts of uranium by deep-rooted trees growing above shallow concealed ore deposits. During the current report period the absorber plant method was used to prospect more than 40 miles of Shinarump conglomerate rim at Deer Flat and Elk Ridge in San Juan County, Utah. Branch tip samples of Utah juniper and other evergreens were collected at 200-foot intervals where the Shinarump is well exposed; where covered, samples were taken at 50-foot intervals. Data for comparison and control were obtained by tree and associated rock sampling in areas known to be mineralized. Eight species of evergreen trees and shrubs were sampled at Elk Ridge in order to provide background data on which to base a large-scale absorber plant prospecting project in 1954.

The results of 1,700 analyses have been received. Areas believed favorable for uranium deposits on geobotanical information coincide with all major known deposits at Deer Flat, and more than 15 concealed or previously unknown favorable rim areas are indicated by other geobotanical anomalies. Physical exploration by the Geological Survey is expected to investigate the most promising of these areas.

Preliminary reports will be transmitted during the next report period. A final report evaluating the usefulness of the geobotanical prospecting at Deer Flat must await the results of drilling of the favorable areas indicated by absorber plant anomalies.

The applicability of geobotanical prospecting by plant analysis was tested in the San Rafael Swell, Emery County, Utah, in conjunction with indicator plant studies. Fifty-two branch-tip samples were collected from juniper trees growing on the Shinarump conglomerate benches. The analyses of these samples have not yet been received. If mineralized rock can be detected through as much as 100 feet of Shinarump conglomerate, then larger areas in the San Rafael Swell would be amenable to the absorber plant method of prospecting.

The Grants district, McKinley and Valencia Counties, N. Mex., was visited in early September to evaluate the results of the 1952 absorber plant sampling when compared to later physical exploration. The small amount of recent exploratory work on the Todilto limestone for the most part supported the predictions of favorable ground indicated by geobotanical prospecting. AEC drilling which began in August should permit evaluation of many of the plant anomalies and the final report on the Grants area will be deferred until the final results of the drilling are available.

Analytical work on geobotanical samples collected on La Ventana Mesa, Sandoval County, N. Mex., showed the variations in uranium content of trees growing on a 65-foot sandstone capping that overlies the uranium-bearing coal. These variations have been contoured to show areas favorable for relatively high uranium content in the underlying coal. A report is in preparation which includes results of the study and recommendations pertinent to physical exploration of the mesa.

A program of geobotanical prospecting was combined with soil studies at Guadalupita, Mora County, N. Mex. Several hundred samples were collected and are being analyzed for metal content.

The indicator plant method of geobotanical prospecting, by P. F. Narten

The indicator method of geobotanical prospecting utilizes the tolerance or need of certain plants for relatively high concentrations of specific elements. In the Colorado Plateau selenium and sulfur are commonly associated with uranium ores of the Morrison formation, and characteristic selenium- or sulfur-requiring flora have been used as a guide to uranium deposits. The distribution of indicator plants around uranium deposits in the Shinarump conglomerate was studied in the San Rafael Swell, Emery County, Utah, during July and August 1953. Work was begun in the vicinity of the selenium-bearing ores of Temple Mountain in the southeast rim of the Swell. In this area over 12 miles of Shinarump outcrop and enclosing formations were systematically examined. Similar examinations were extended to include almost all mineralized Shinarump outcrops within the inner periphery of the Swell, as well as the associated non-mineralized Shinarump, Moenkopi, and Chinle formations, and a few Jurassic and Quaternary deposits. The examinations consisted of mapping all indicator plants in selected areas at intervals of approximately 6 miles or less; for most areas a complete list of the flora on each formation was prepared.

Preliminary analysis of the data suggests that the use of indicator plants in the San Rafael Swell would be best suited to the selenium-rich rocks of the Temple Mountain-Shinarump Mesa area. Outside of that area uranium-mineralized rocks are rarely defined by indicator plants on the Shinarump benches. Pending receipt and appraisal of sample analyses and a more complete study of the geobotanical significance of 125 plant species on which data were accumulated, the use of indicator plants in the San Rafael Swell remains possible, although at present the results are not encouraging.

Reconnaissance examination of the uranium deposits in the Salt Wash member of the Morrison formation near Trachyte Ranch on the east side of the Henry Mountains, Garfield County, Utah, has shown that *Astragalus sp.* might be useful in delimiting favorable ground although the individual uranium deposits in this area appear small. Reports from local prospectors indicate that they have used the *Astragalus* plants effectively in prospecting.

At Poison Canyon in the Grants mining district, McKinley County, N. Mex., *Astragalus pattersoni* on the Morrison sandstone clearly defined later discoveries of two large ore bodies and check well with radioactivity anomalies discovered by the AEC. Drilling planned by the AEC in this area will be based in part on plant distribution.

A TEM report summarizing the results of the study of indicator plants on Carpenter Ridge and at the Jo Dandy group, Montrose County, Colo., is in preparation.

Resource appraisal

Ore distribution study, by J. D. Strobell, Jr.

Compilation of maps showing known uranium deposits and favorable ground within the Salt Wash member of the Morrison formation is in progress. Maps covering the Gateway, Uravan, Paradox, Gypsum Valley, Bull Canyon, and Slick Rock districts are partially complete and can be examined at the Grand Junction office of the Geological Survey. The distribution pattern of the deposits will be analyzed to determine trends of ore concentration and to relate the pattern to such factors as geologic structures, erosion surfaces, and inferred ground-water surfaces.

Much information must still be compiled and studied to provide a basis for valid statistical and geologic conclusions but a progress report (TEM-632, in preparation) shows the methods and scope of the work and summarizes the preliminary study of the Gateway and Uravan mining districts. Based on incomplete data this preliminary study indicates that nearly 4 percent of the ground tested in the Uravan mining district is underlain by uranium deposits and nearly 30 percent of the ground is favorable. Less than 1 percent of the ground tested in the Gateway mining district is underlain by deposits and slightly less than 10 percent of the ground is favorable. The "average" size of the deposits is about three times larger in the Uravan district than in the Gateway district, and there is a greater proportion of larger deposits in the Uravan district. The data in these and the other districts will be compiled and analyzed further and reports prepared in such units as may yield significant relationships. The supplementary study of the regional distribution of uranium and vanadium grades, which was planned to begin during this report period, was postponed.

Reconnaissance resource appraisal, by W. I. Finch

Progress of the reconnaissance resource appraisal has been summarized in TEI-328, and a more detailed and comprehensive report is in preparation. A report on the geology of the Shinarump No. 1 mine, Seven-Mile Canyon area, Grand County, Utah (TEI-287) is being processed for transmittal to the AEC.

The Upper Triassic Shinarump conglomerate consists mainly of light-colored sandstone and conglomerate in even-bedded layers and filling shallow and deep stream channels at the base of the Upper Triassic Chinle formation. As shown by the stratigraphic studies, the sandstone and conglomerate at the base of the Chinle is not everywhere the same unit although it has consistently been referred to as the Shinarump conglomerate.

Uranium deposits occur in the lower third, and more commonly in the basal few feet, of the Shinarump. The uranium deposits are commonly associated with the following features that may serve as guides to ore: 1) channels and lenses along the margins of the Shinarump deposition; 2) clay and mudstone; 3) carbonaceous material; 4) mudstone alteration; 5) iron stains; and 6) sulfide minerals.

Three belts of ground favorable for better than average uranium deposits have been outlined. In Monument Valley, Utah and Ariz., significant deposits lie in an arcuate belt about 8 miles wide and 40 miles long. In Monument Valley, the Shinarump conglomerate consists of deep channels in an irregular zone whose northern limit trends northwestward into the Circle Cliffs area, Utah. Significant deposits occur near the bottom of deep channels that appear to form a channel system along and parallel to the northern margin of Shinarump deposition. In the area between Monument Valley and White Canyon, the Shinarump is absent for the most part and, where present, does not contain any known deposits. To the north in the White Canyon, Utah, and Capitol Reef, Utah, areas the Shinarump is discontinuous; where present, it mostly fills shallow channels and is absent between these channels. The majority of the significant deposits lies in a favorable belt from 2 to 8 miles wide and about 30 miles long in the eastern part of White Canyon. These significant deposits occur near the bottom of shallow channels that appear to form a channel system along and parallel to the margin of the Shinarump deposition. North of White Canyon the Shinarump consists of an even-bedded sandstone. This even-bedded Shinarump pinches out along an east-west line north of the junction of the Green and Colorado Rivers. Channels are sparse in the even-bedded sandstone except along the northern edge where channels are common. These channels appear to form a channel system that may extend eastward to the Big Indian Wash area and westward into the San Rafael Swell. A belt of favorable ground, about 10 miles wide and 100 miles long, is formed by the alignment of significant deposits and geologically favorable ground in the southern half of the San Rafael Swell, the area north of the junction of the Green and

Colorado Rivers, and the Big Indian Wash area. The boundaries of this belt are formed in part by the channel system along the margin of Shinarump deposition.

In the course of the study, the radioactivity of modern stream gravels was measured and studied by R. T. Chew, III. Anomalously high radioactivity in the detritus transported by present streams is a useful prospecting aid under certain conditions, and such signs of deposits can be picked up as much as one mile downstream.

Mineralogic studies

General mineralogic studies, by T. Botinelly, A. D. Weeks, and D. H. Johnson

Samples for mineralogic and petrographic study were collected from the Edgemont area in South Dakota, the Pumpkin Buttes area in Wyoming, and the Colorado Plateau. The ores of the Edgemont area contain tyuyamunite, rauvite, hewettite, corvusite, barite, and native selenium; this mineral association is similar to that found in the oxidized vanadiferous ores of the Colorado Plateau. Minerals identified from the Pumpkin Buttes area include tyuyamunite, carnotite, uranophane, liebigite, and bayleyite.

TEI-334, "Identification and occurrence of uranium and vanadium minerals on the Colorado Plateau," by A. D. Weeks and M. E. Thompson and transmitted in August 1953, contains physical properties, X-ray data, and some results of chemical and spectrographic analyses of 24 uranium and 17 vanadium minerals of the Colorado Plateau. Data are presented on the types of ore, and the mineral associations and distribution of the types.

The ore is classified on the basis of whether the uranium is associated with vanadium or with copper and other metals; each type is subdivided into highly oxidized or unoxidized types.

The oxidized uranium-vanadium ore is characterized by the presence of carnotite or tyuyamunite. Other secondary uranium minerals may be present in small amount. The most abundant vanadium minerals are vanadium hydromica, roscoelite, and corvusite. Accessory vanadium minerals are secondary quinquivalent vanadium minerals such as hewettite, pascoite, and rossite. This type of ore is found in the Uravan mineral belt of southwestern Colorado; the Temple Mountain area, Emery County, Utah; and in Monument Valley, Utah and Ariz.

The unoxidized uranium-vanadium ore is characterized by its black color and the presence of primary uranium minerals, pitchblende and "coffinite" (a new uranium mineral to be described). The vanadium minerals are montroseite and other trivalent and quadrivalent vanadium oxides. This type of ore is usually found in the deeper ore bodies, as in the Long Park area, Montrose County, Colo., or where an ore body has been exposed recently by erosion as in Lumsden Canyon, Mesa County, Colo., or La Sal Creek, Montrose County, Colo., and San Juan County, Utah.

The oxidized non-vanadiferous ore contains a wide variety of secondary uranium minerals, such as hydrated sulfates, oxides, carbonates, and phosphates. No one mineral predominates. Copper is the chief associated metal and occurs as secondary minerals such as malachite, azurite, and chalcanthite.

The unoxidized non-vanadiferous ore contains pitchblende and probably coffinite. Where this type of ore is best developed (Happy Jack mine, San Juan County, Utah) the uranium minerals are associated with copper sulfides such as chalcopyrite, chalcocite, bornite, and other sulfides.

This type of ore is found in the White Canyon mining district and at scattered localities in the Green River, San Rafael Swell, and Henry Mountains districts.

Any of the unoxidized types of ore may grade into the oxidized types or may be found as unoxidized remnants in an oxidized ore body.

In the Colorado Plateau new localities were found for andersonite and fervanite. New minerals found include a hydrated sodium vanadate ($Na_2O.3V_2O_5.3H_2O$) and a potassium uranyl arsenate belonging to the torbernite group. Hewettite and metahewettite which were originally described as having the same formula with nine molecules of water are being restudied after discovery that the fully hydrated form readily loses six molecules of water. The original definition of metahewettite is not clear and none of the present specimens have indices of refraction similar to those given for metahewettite. Some fully hydrated material has been purified for dehydration studies. Liebigite was synthesized to check the formula given in the literature; the occurrence at Pumpkin Buttes suggests that liebigite is related to bayleyite.

TEI-335, "Montroseite, a new vanadium oxide from the Colorado Plateaus," by A. D. Weeks, E. A. Cisney, and A. M. Sherwood was transmitted in July 1953 and is published in the American Mineralogist for November-December 1953. Descriptions of "navajoite", a new vanadium oxide, and "rabbittite", a new calcium magnesium uranyl carbonate, are in preparation.

Chemical and spectrographic analyses have been completed on paired samples of red and gray clay associated with the ore-bearing sandstone and a report is in preparation on the results of these analyses.

Study of the mineralogy of the Monument No. 2 mine, Apache County, Ariz. was continued during the report period. Detailed maps and wall sketches at a scale of 1 inch to 10 feet were made of important parts of the mine. A grayish-blue efflorescent mineral was identified as ilsemannite; this is the first molybdenum mineral found in this mine. A punch-card system for use in mineral identification based on X-ray diffraction, chemical, physical, and optical data is being developed. A progress report summarizing the results is in preparation and is planned for transmittal in the next report period.

Distribution of elements project, by W. L. Newman

The distribution of elements project is divided into three phases: (1) distribution of elements in bedded ore deposits, (2) distribution of elements in sedimentary rocks, and (3) distribution of elements in igneous rocks. About 1,000 samples of rocks and ores have been submitted for analysis. Analyses have been completed on most of this group; compilation and study of the chemical data is in progress.

A TE report, "A statistical analysis of an ore body in the Legin Group area, San Miguel County, Colorado," by A. T. Miesch and E. M. Shoemaker (in preparation) summarizes preliminary results of a study of the distribution of uranium and vanadium oxides and calcium carbonate in a single ore body. Statistical parameters of the assays show that these compounds have definite distribution patterns in the ore body. Uranium oxides and vanadium oxides do not occur with large percentages of calcium carbonate; the correlation coefficients between the uranium-vanadium and calcium carbonate in this ore body are, in each instance, negative. The study has developed a method for determining the standard deviation of grade throughout an ore body; similar methods of statistical analysis should be of use to all geologists concerned with reserve appraisals.

Preliminary results of the study of the distribution of elements in sedimentary rocks and bedded ore deposits suggest that uranium deposits are surrounded by "halos" of heavy metals which may be used as guides to ore. These metals can be rapidly detected by recently developed colorimetric analyses. The distribution of heavy metals will be studied further in areas of known ore deposits and in areas away from known ore deposits in order to test the applicability of geochemical prospecting methods.

TE reports, "Reconnaissance geology of the Ute Mountains, Colorado," by E. M. Shoemaker and W. L. Newman (in preparation), and "Lamprophyre intrusions and associated uranium deposits of the Navajo-Hopi Indian Reservation," by E. M. Shoemaker (in preparation) summarize some of the preliminary results of studies of distribution of elements in igneous rocks. Geologic evidence suggests that uranium deposits near the Ute Mountains and in the diatremes are closely associated with igneous activity and may be of hydrothermal origin. The studies suggest that many of the same minor elements that are found associated with uranium deposits tend to be concentrated in ferro-magnesian minerals which crystallized early in the differentiation process. It is hypothesized that acidic solutions relatively rich in radioactive metals were concentrated during the course of differentiation; that these solutions hydrated the ferro-magnesian minerals and thereby released some of the minor metals, including vanadium, and carried the metals out of the igneous bodies during the final stages of consolidation of the magma.

During the next report period compilation of data and preparation of a preliminary report will be continued. The preliminary report will summarize the results of all aspects of the distribution of elements project.

Cenozoic studies

The Cenozoic studies have been recessed during this report period, except for the editing and processing of a comprehensive report which summarizes what is known concerning the Cenozoic history of the Colorado Plateau. Although the project has been recessed, contributions to the knowledge of the details of the Cenozoic history have been made by the regional mapping projects.

Geophysical district studies
by R. A. Black

Field work on the district studies project began in April 1953 and, with the exception of the electric logging program, was recessed in November 1953. Electrical resistivity, seismic refraction, magnetic and self-potential surveys, and experimental surface-inhole electrical studies were made during the 1953 field season. Electric logging of drill holes is being done in connection with an exploration program to test directly the geologic utility of the method in guiding exploration.

Self-potential and electrical resistivity surveys have been completed in the Deer Flat area, San Juan County, Utah. The association of sulfide minerals with the uranium ore in the Hideout mine in this area suggested the use of self-potential methods of tracing the ore-bearing channel in the vicinity of the mine. Measurements were made on a bench behind the mine, but no correlation existed between the small anomalies obtained and the ore-bearing channel. Electrical resistivity horizontal and depth profiling techniques were used in Deer Flat to locate faults or fractures, which might be associated with the ore deposits, and to locate channel trends. "A preliminary report on geophysical investigations of the Deer Flat area, White Canyon district, San Juan County, Utah," by W. H. Jackson (in preparation) summarizes the results of this study.

A geophysical survey, employing magnetic, self-potential, and electrical resistivity horizontal profiling methods, was made near Grants, N. Mex. (1) to determine the cause of a magnetic low previously discovered in this area with the airborne magnetometer, (2) to attempt to trace under alluvial cover several major faults which might affect exploration drilling in the area, (3) to attempt to detect shallow ore concentrations where associated with hematite, and (4) to investigate a series of linear geobotanical anomalies in the area. The magnetic measurements showed that the magnetic low was an edge effect of a nearby lava sheet, but no magnetic anomalies were obtained over the shallow ore bodies or the geobotanical anomalies, and the faults could not be traced magnetically. The self-potential survey showed no anomalies which could be correlated with the shallow ore bodies or with the faults or the geobotanical anomalies. Preliminary examination of the electrical resistivity data indicates that the horizontal profile data may delineate some of the fault trends. A report will be prepared on the results of this work during the winter months.

Electrical resistivity measurements were made in the vicinity of the Monument No. 2 mine, Apache County, Ariz. to determine if the Monument No. 2 channel extends under the sand-covered Cane Valley area. An area approximately 3,000 feet by 1,000 feet was investigated. The data are being interpreted by theoretical means, and a report on the results will be issued during the next report period.

Electrical resistivity surveys were made on Holiday and Oljato Mesas in the Monument Valley area, San Juan County, Utah. The measurements on both Holiday Mesa and Oljato Mesa were for the purpose of delineating the Shinarump channel pattern on the mesas. The field data collected at Holiday Mesa are being compiled for theoretical interpretation and a report on the results of this work will be prepared during the winter months. The electrical measurements on Oljato Mesa were made in a test area roughly 1 mile by 2 miles. Seismic refraction measurements were made in this same area. A detailed comparison will be made of methods of mapping the buried contact of the Shinarump conglomerate and the Moenkopi formation so as to delineate channels. These data are being compiled for interpretation during the winter months. If favorable results are obtained, recommendations for drilling in these areas will be made. A combined report on the electrical resistivity and seismic results will be issued prior to resumption of field activities in the spring of 1954.

Further tests of the ability of the seismic refraction method to map the Shinarump-Moenkopi contact and to delineate channel trends were made on the Hunts and Oljato Mesas in Monument Valley, Utah and Ariz. The air shooting method was used during these tests. The results of the tests indicated that, with certain limiting conditions, seismic refraction surveys could be used to map the contact of the Moenkopi formation and the Shinarump conglomerate and to delineate channel trends.

Electrical resistivity measurements were made in the Spud Patch area, San Miguel County, Colo., to obtain resistivity depth curves suitable for theoretical interpretation. Electric logging at Spud Patch in 1952 suggested that surface resistivity curves in this area should approximate a theoretical five layer curve, with the resistivity variations in the Salt Wash being shown at Wenner electrode spacings between 150-400 feet. The measurements made in Spud Patch will be used to test the validity of this suggestion.

An electric logging unit has been operating in Long Park, Montrose County, Colo., in conjunction with the current Geological Survey drilling project in that area. Electric logging at Spud Patch and several other localities on the Colorado Plateau during 1952 indicated that electric logs could be used to obtain indices of the favorability for ore within sandstones of the Salt Wash member of the Morrison formation, as well as porosities, permeabilities, and water salinities and saturations. The present program is intended as an objective test of the usefulness of electric logs as exploration tools. In addition to the routine electric logging in Long Park, electric logs of drill holes BCX-1, BCX-2, and LP-530 were obtained. These will be used in connection with original-state core studies on cores from these drill holes.

A magnetic survey was completed at Temple Mountain in the San Rafael Swell, Emery County, Utah, to determine if a buried igneous body is associated with the altered and collapsed zone in this area. No detectable anomaly was obtained over the altered zone at Temple Mountain itself, but a strong positive anomaly of several hundred gammas was found offset to the southwest. This anomaly is superimposed on a strong regional gradient. Operations in this area have been recessed pending the results of airborne magnetic measurements to be made in this area in the spring of 1954. A preliminary report on the results of the ground magnetic work is being prepared.

A magnetic investigation of the Round Mountain stock in Castle Valley, Grand County, Utah, has been completed. This survey was made to determine if

Round Mountain was connected to the La Sal Mountains by a shallow lateral feeder. The results of the survey indicate that no shallow lateral feeder exists, and that Round Mountain is fed vertically from a point offset slightly to the southeast of the present igneous outcrop. Information as to the shape of the stock was also gained from this survey. TEI-342, "A magnetic investigation of the Round Mountain stock, Castle Valley, Utah," by R. A. Black (in preparation) summarizes the results of this study.

Experimental surface-inhole electrical measurements were made during this report period. Measurements were made in Salt Wash sandstone at Spud Patch, San Miguel County, Colo., to try to delineate directional resistivity trends from drill holes. Preliminary results indicate that directional resistivity trends obtained in the Spud Patch area may correlate with favorability trends in the Salt Wash in that area. Surface-inhole measurements were also obtained in the Shinarump conglomerate at Frey Canyon, Utah, but, although the results look promising, not enough data have been obtained to determine that channel trends can be located definitely by these measurements. A preliminary report on the results of these measurements is in preparation and a final report will be prepared in the spring of 1954 after the interpretation has been completed.

Present plans are to resume field operations in April 1954 with an electrical resistivity crew and a seismic refraction crew for geophysical prospecting surveys. Specific areas to be tested will be selected on the basis of reports by field geologists on field work done in Morrison and Shinarump areas during the 1953 field season. Electrical well logging will be continued in connection with exploration projects. The electric logging equipment may be combined with the gamma-ray logging units. Surface-inhole work will be resumed in June, possibly on an exploratory basis. Magnetic ground surveys will be made where required to provide geologic information on igneous intrusives and to detail small anomalous areas discovered by the regional airborne magnetometer survey. Thermal studies will be made in the Temple Mountain area to determine if temperature anomalies are associated with the altered zones in this area. Some experimental shallow reflection seismic studies may be made in selected areas.

Regional studies
by H. R. Joesting

Regional geophysical studies of the Colorado Plateau started in July, 1953. The project is concerned with obtaining and analyzing regional magnetic, gravimetric and other geophysical and geological information in order to define as completely as possible the regional structural trends, buried intrusives, and topographic and compositional changes in the basement; and to determine the relationship between regional geologic features and the occurrence of uranium.

Aeromagnetic surveys

Aeromagnetic surveys of the Colorado Plateau flown during fiscal year 1954 and earlier are shown in figure 3. Magnetic contour maps of the Uravan area have been compiled and will be released as a Trace Elements Investigations Report.

During the reporting period a total of 11,500 traverse miles were flown, including special surveys over the Abajo, Sleeping Ute and Navajo Mountains, and over the Boundary Butte anticline in southeast Utah. In addition, an area was flown in Arizona, south of Monument Valley. All lines, except base lines, were flown east-west and were spaced one mile apart.

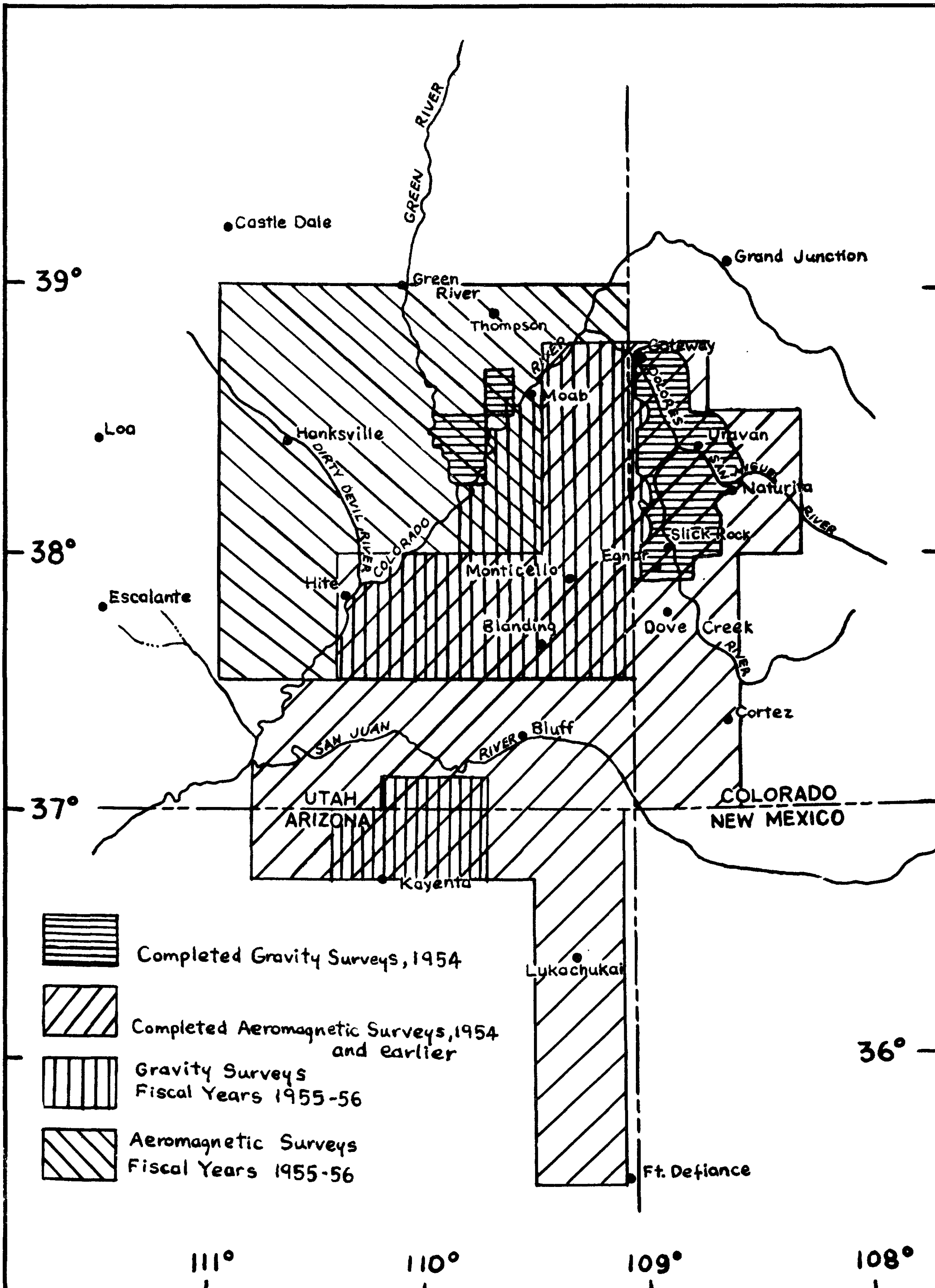


FIGURE 3.--GRAVITY AND AEROMAGNETIC COVERAGE

Gravity surveys

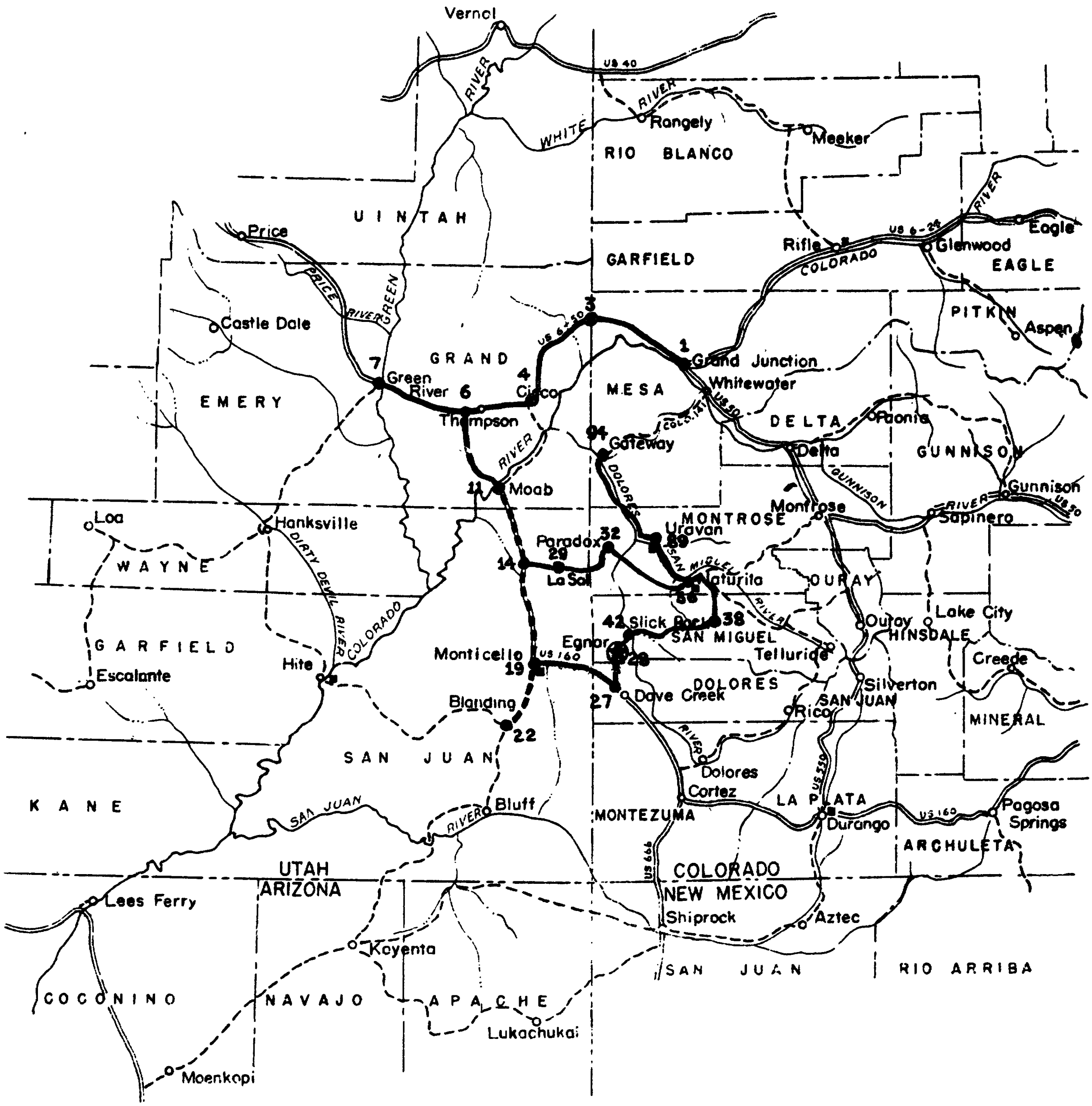
Regional gravity studies in the Colorado Plateau were initiated with the establishment of a network of base stations, a relatively detailed survey of the Gateway-Uravan-Egnar area of Colorado and a less detailed survey of the area between the Green and Colorado Rivers (figs. 3 and 5). A total of about 850 gravity stations were established, including about 70 base stations. Approximately 630 of these stations comprise the survey in the Uravan mineral belt area, 16 stations make up a profile from Blanding, Utah, west to Elk Ridge, and the remainder are in the inter-river area.

A network of base stations has been established as shown in figure 4.

Gravity surveys are now being run in that part of the inter-river area, between the Green and Colorado Rivers, for which topographic coverage is available.

Compilation of the Bouguer isoanomaly gravity map for the Gateway-Uravan-Egnar area is proceeding, but is slowed somewhat by the time required to make terrain corrections. It is estimated that the map will be completed by the end of January, 1954. Compilation will begin shortly on the map for the portion of the Inter-River area surveyed.

In view of the accuracy of the survey of the Gateway-Uravan-Egnar area it is probable that the subsequent gravity map will have a contour interval of one milligal except in the areas where more accurate control is available. In these areas the map will probably be contoured at an interval of .5 milligal. It is to be noted that an effor of 10 feet in elevation corresponds to an error of .6 mgal. in the Bouguer anomalies.



BASE LINE LOOPED BY 3-STEP METHOD

BASE LINE LOOPED AT INTERVALS OVER ABOUT 50% OF ITS LENGTH

11 ● SELECTED BASE STATIONS WITH NUMBER

28 PENDULUM GRAVITY BASE STATION

FIGURE 4.--GRAVITY BASE LINES

Fig. 5—Colorado Plateau Regional Geophysical Studies. Gravity Coverage in the Gateway-Uravan-Egnar Area, Colo. (See page 283.)

The direct relationship of radioactivity with increasing spread of grain-size distribution and increasing water content, and the inverse relationship with skewness apparently holds somewhat more consistently than the inverse relationship between permeability and radioactivity. In the more radioactive intervals, however, the inverse relationship between radioactivity and permeability is very good.

Analysis of the pore water recovered from cores indicates that, as regards identity and relative concentration of commoner anions, ground water collected from surface springs and mine openings are quite similar to the pore water of the core samples. The water in the pore space, however, contains much greater concentration of the commoner anions; in fact, the pore water is probably a saturated solution, with the high concentration attributable to evaporation underground.

Laboratory tests of the elastic constant properties indicate that the velocity of propagation of sound waves in the Salt Wash member of the Morrison formation may be greater in those localities where the mineralization is poor or absent and slower where ore occurs. Because of the paucity of samples, this conclusion must be considered as very tentative. However, if the Salt Wash member does generally show higher velocity in poorly mineralized or unfavorable ground, a seismic survey may show a higher velocity surface cutting across a stratigraphic horizon in the Salt Wash, rising in the direction of unfavorable ground and descending in the direction of favorable ground.

Fig. 5—Colorado Plateau Regional Geophysical Studies. Gravity Coverage in the Gateway-Uravan-Egnar Area, Colo. (See page 283.)

Preliminary conclusions

As no systematic examination of magnetic or gravimetric data has yet been made, only a few tentative conclusions can be drawn.

Small, positive magnetic anomalies were observed over the laccolithic La Sal, Abajo, Carrizo and Sleeping Ute Mountains. These would be anticipated from rocks of intermediate to acid composition. A small positive anomaly was also observed over Navajo Mountain; from this it is inferred that Navajo Mountain is underlain by a laccolithic intrusion.

A broad, positive magnetic anomaly of relative high amplitude extends south from the Abajo Mountains to Blanding. Another prominent anomaly was found to coincide approximately with part of Comb Ridge, and still another with the Boundary Butte anticline. There appears to be no direct and simple relation between these large magnetic features and surface geology, and no attempt has yet been made to relate them to subsurface geology.

Plans

Aeromagnetic surveys of most of the north and west portion of the Colorado Plateau (fig. 3) will be flown in fiscal year 1955, and the remainder will be flown in fiscal 1956. It is possible, however, that the northern part of the area, including the San Rafael Swell, will be flown in February and March, 1954, provided weather and other operating factors are favorable.

Compilation of aeromagnetic data equivalent to about 3,000 traverse miles is scheduled for the remainder of fiscal year 1954. In addition, arrangements have been made to compile partly the special high altitude surveys over the Abajo, Ute, Carrizo, and Navajo Mountains in the Grand Junction office of the Survey.

Adequate topographic maps of much of the Plateau are either on hand or in preparation, and plans for the regional gravity surveys are based on the availability of these maps. Gravity surveys of the inter-river area between the Green and Colorado Rivers will be made during the remainder of fiscal year 1954 (fig. 3); and a start will probably be made in the Monument Valley area in southeast Utah and northeast Arizona.

Original-state core studies
by G. E. Manger

Core samples from four drill holes have been obtained by drilling with oil-base mud and air as the circulating mediums. The core samples were carefully sealed in the field to avoid loss of interstitial contents. To date, samples of rock matrix with and without interstitial contents have been subjected to an extensive series of physical tests, and the recovered interstitial pore water has been subjected to chemical tests. Significant results obtained during the present reporting period are described below.

Data from detailed textural analysis have been collated with detailed analysis of physical properties including permeability and water content of the pore space, and with radioactivity measurements. The combined information shows that radioactivity in the formation bears a close direct relationship with increasing spread of the grain size distribution and with increasing water saturation of pore space, and a close inverse relationship with permeability (dry air) and with departure from a symmetrical distribution of grain size (skewness). The crux of this relationship seems to lie neither in the absolute values of the size distribution parameters nor in the absolute values of physical properties measurements, but in the magnitude of these values relative to values in immediately adjacent rocks.

The direct relationship of radioactivity with increasing spread of grain-size distribution and increasing water content, and the inverse relationship with skewness apparently holds somewhat more consistently than the inverse relationship between permeability and radioactivity. In the more radioactive intervals, however, the inverse relationship between radioactivity and permeability is very good.

Analysis of the pore water recovered from cores indicates that, as regards identity and relative concentration of commoner anions, ground water collected from surface springs and mine openings are quite similar to the pore water of the core samples. The water in the pore space, however, contains much greater concentration of the commoner anions; in fact, the pore water is probably a saturated solution, with the high concentration attributable to evaporation underground.

Laboratory tests of the elastic constant properties indicate that the velocity of propagation of sound waves in the Salt Wash member of the Morrison formation may be greater in those localities where the mineralization is poor or absent and slower where ore occurs. Because of the paucity of samples, this conclusion must be considered as very tentative. However, if the Salt Wash member does generally show higher velocity in poorly mineralized or unfavorable ground, a seismic survey may show a higher velocity surface cutting across a stratigraphic horizon in the Salt Wash, rising in the direction of unfavorable ground and descending in the direction of favorable ground.

Wyoming

Reconnaissance
by J. D. Love

Gas Hills area

In the Gas Hills area of central Wyoming (see fig. 6) uranium minerals have been discovered in the Wind River formation of early Eocene age, in middle and late Eocene rocks, and in the Thermopolis shale of early Cretaceous age. The mineralization is concentrated in clayey and conglomeratic sandstone and in carbonaceous shale; the uranium occurs chiefly in the form of a greenish-yellow highly fluorescent mineral tentatively identified as uranospinite, $Ca(UO_2)_2(AsO_4)_2 \cdot 8\text{-}12H_2O$. Analyses of the samples are:

Rock	Formation	Percent U
Sandstone	Wind River	1.87
Carbonaceous shale	Wind River	0.062
Sandstone	Middle and late Eocene	0.078
Shale	Thermopolis (directly below Wind River)	0.041

The approximate boundaries of the area of above-normal radioactivity in the Gas Hills area have not been determined, although anomalously high radioactivity is known to occur at intervals throughout an area extending about 20 miles northeast and southwest and 5 miles northwest and southeast.

Mayoworth area

Uranium minerals, probably carnotite or uranophane or both, occur in the basal limestone of the Upper Jurassic Sundance formation about 2 miles southwest of the abandoned postoffice of Mayoworth (fig. 6),

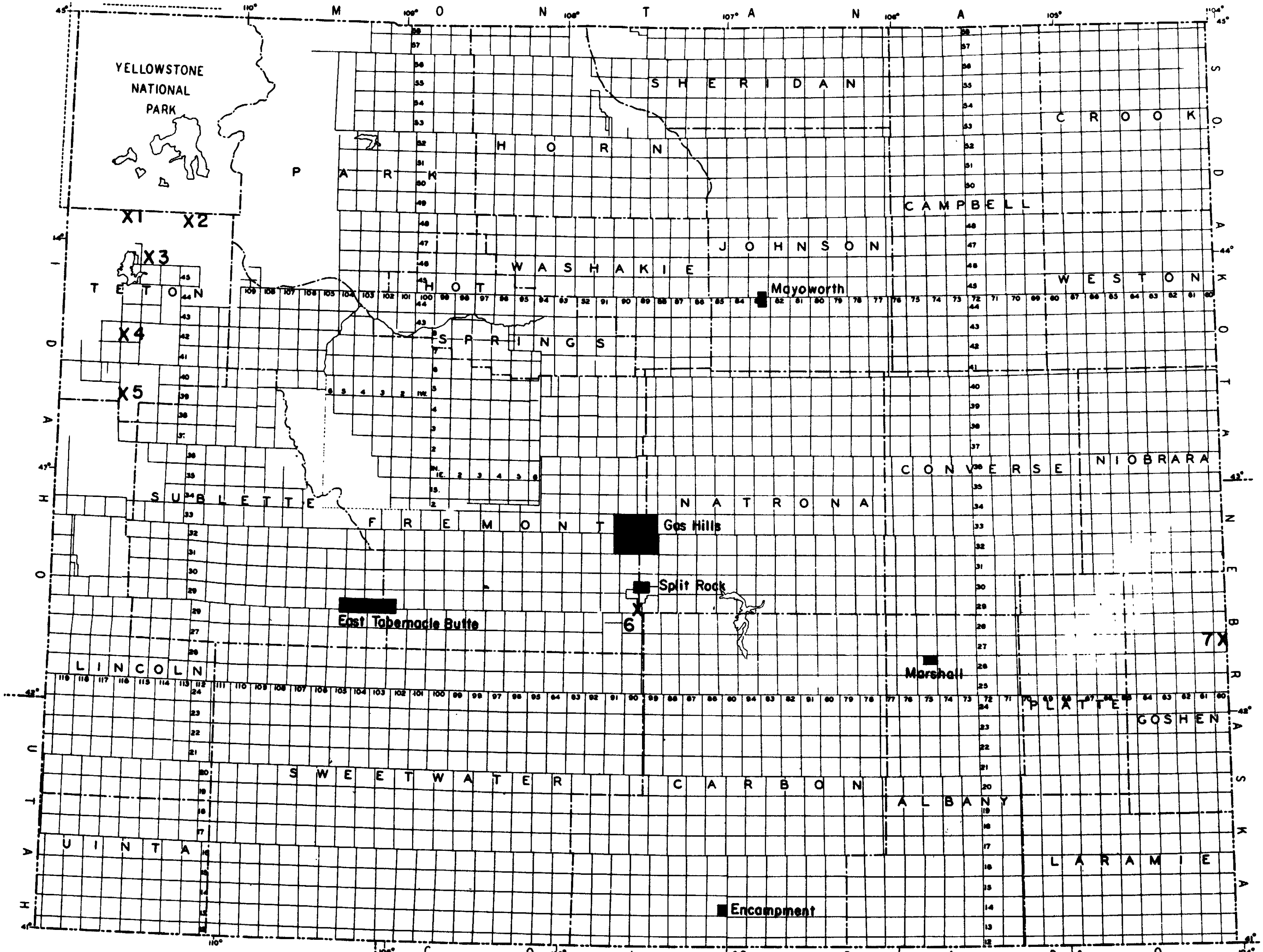


FIGURE 6.--MAP OF WYOMING SHOWING LOCATION OF AREAS EXAMINED AND SAMPLED, JUNE 1-NOV. 30, 1953 By J. D. Love

Johnson County. In this area numerous spots of considerable radioactivity were noted along the outcrop of the oolitic limestone for a distance of more than half a mile. The limestone is 9 feet thick and the upper 2 feet shows abundant yellow staining along fractures and to a lesser extent in and around the oolites. A scintillation counter here reads a maximum of 1.5 mr/hr; half a mile southeast at the top of the same limestone the reading is 2 mr/hr but no mineralization is visible. A chip sample of the surficial 3 inches of limestone contains 0.17 percent eU, 0.030 percent U, and 0.10 percent V_2O_5; and a selected sample from the northwest end of the area examined contains 0.70 percent eU, 0.71 percent U, and 0.56 percent V_2O_5.

East Tabernacle Butte area

This area (see fig. 6) was flown with airborne scintillation equipment by the Geological Survey and five anomalies were recorded. When these were checked with a hand scintillation counter no significant radioactivity was found; but it is possible that additional examination with carborne and hand equipment may indicate points of interest.

Marshall area

In the Marshall area of Albany County (see fig. 6) manganese occurs in the upper part of the Casper formation, the exposed parts of which are of Pennsylvanian age, along its contact with the overlying White River formation of Oligocene age. The manganese occurs on rounded knobs which once were buried by White River rocks and later exhumed. A random sample of cherty manganiferous limestone from one of the prospect pits which have been dug in the area contains 0.015 percent eU, 0.014 percent U, and 0.24 percent V_2O_5. A fossil bison bone from deposits of Pleistocene age overlying the White River formation contains 0.028 percent eU, 0.086 percent U, and 0.06 percent V_2O_5.

Split Rock area

The possibilities of uranium deposits in the Pliocene (?) rocks of the Split Rock area (see fig. 6) were described in 1952 (Love, TEM-282). Additional samples were collected during the past six months. A surface sample from one limestone deposit which showed a maximum scintillation counter reading of 1 mr/hr contained 0.028 percent eU, 0.023 percent U, and less than 0.05 percent V_2O_5; another and larger deposit showing the same reading contained 0.024 percent eU, 0.001 percent U, and 0.06 percent V_2O_5. A second sample contained 0.034 percent eU, 0.007 percent U, and 0.06 percent V_2O_5. A white tuffaceous shale believed to be stratigraphically directly below the lenticular limestone is exposed 1/2 mile to the northeast of the limestone outcrops; a sample of this rock contains 0.011 percent eU, 0.013 percent U, and 0.10 percent V_2O_5. Fossil bone fragments from a sandstone bed about 30 feet below this bed contain 0.17 percent eU, 0.015 percent U, and 0.27 percent V_2O_5. It is believed that a carborne scintillation detector can be used to advantage in further reconnaissance in this area.

Other localities

Cursory examinations were made of seven localities which are numbered consecutively on fig. 6.

No.	Locality	Rock	Analyses, percent eU	U	V_2O_5
1	Flagg hot springs	Psilomelane	0.019	0.003	0.08
2	Mink Creek	Fossil bone from white tuff	0.005	0.006	0.10
3	Pilgrim Creek	Fossil bone from gray tuff	0.005	0.005	0.06
4	Jackson Elk Refuge	Carb shale	0.002	-	-
		Tuff	0.003	-	-
5	Camp Davis	Fossil bone from white tuff	0.020	0.021	0.06
6	Split Rock Miocene locality	Fossil bone from gray sandstone	0.020	0.020	0.11
7	Spoon Buttes	Fossils from gravel	0.027	0.028	0.08
		Sandstone	0.003	0.003	0.05

Powder River Basin, Wyoming
by D. F. Davidson

Uraniferous deposits in the Powder River Basin are of two types: (1) small concretionary masses containing manganese, iron, vanadium, and uranium; and (2) disseminations in sandstone containing little or no manganese or iron. Both types occur in lenticular, cross-bedded, medium- to coarse-grained, reddish gray sandstones that are 450 to 900 feet above the base of the Wasatch formation of Eocene age.

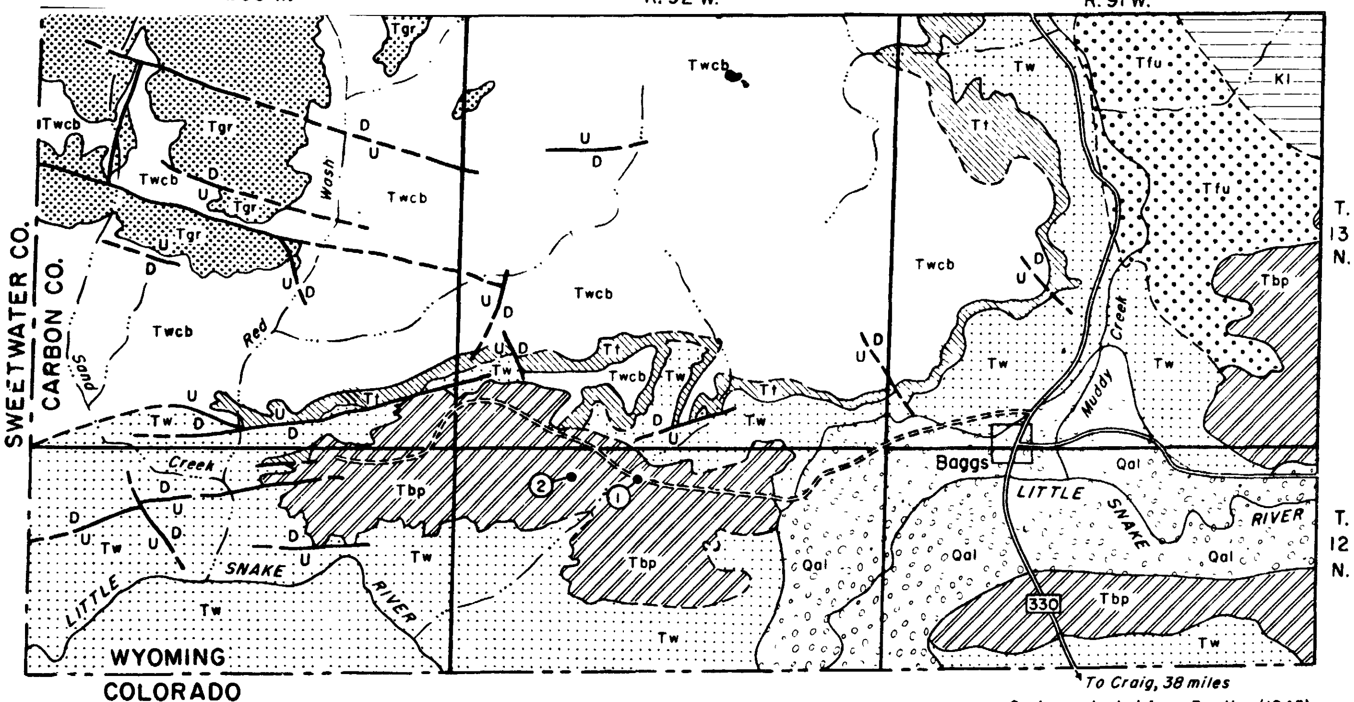
Geologic mapping at scales of 1:18,000, 1:12,000, and 1:28,000 was done in the Butte 2 SW, Sussex 1 NE, and Sussex 1 SE 7 1/2-minute quadrangles. Five uranium-bearing areas were mapped at scales ranging from 1:600 to 1:2,400. Stratigraphic sections of the Wasatch formation were measured and approximately 3,000 feet of Wasatch core from holes drilled by the Bureau of Mines for the AEC were described. A large number of samples were taken for analysis.

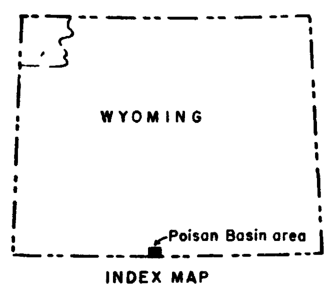
Several tentative guides useful in the search for hidden uranium deposits were developed; (1) the occurrences appear to be restricted to certain traceable stratigraphic units; (2) they appear to be intimately associated with concentrations of carbonate minerals, local reddening of normally brown sandstone, and certain sedimentary structures in sandstones; and (3) they may be indirectly related to fracturing, which in turn may be related to regional structure.

The winter will be spent in compilation and study of all mapping to date and all available stratigraphic information, as well as study of thin sections and assay data of samples. An interim report on the Pumpkin Buttes uranium deposits will be completed during the first half of 1954.

Poison Basin area, Carbon County, Wyoming
by J. D. Vine and G. E. Prichard

Uranium-bearing sandstone was discovered on October 15, 1953, in the Browns Park formation of the Poison Basin area about seven miles west of Baggs, Carbon County, Wyoming. (See PRR's F-1013 and F-1014). Occurrences extend over a distance of at least one mile (secs. 4 and 5, T. 12 N., R. 92 W.) as shown by the two locality numbers on the geologic map (fig. 7). The discovery was reported to AEC personnel on October 17th.





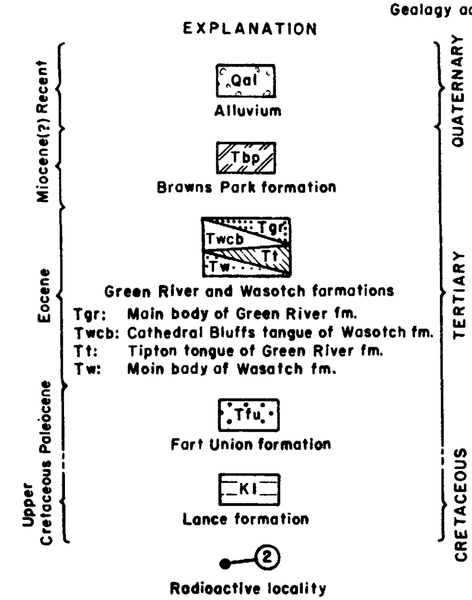
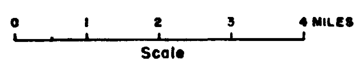


FIGURE 7.--GEOLOGIC MAP OF POISON BASIN AREA, CARBON COUNTY, WYOMING



They immediately conducted an aerial radioactivity survey, the results of which were subsequently posted as an AEC airborne anomaly location map of Carbon County, Wyoming, released November 15, 1953. The U. S. Geological Survey has also flown an aerial radioactivity survey, the results of which are not yet available. Analyses of preliminary samples from the area are very encouraging, as shown below:

Pit No.	Field No.	Lab. No.	eU (percent)	U (percent)	Description
			Locality No. 1.		
1	VW3-89	D-98776	0.86	0.90	Grab Dk. brown sandstone
1	90		0.43	0.39	18" Brown sandstone
1	401		0.5	0.69	Grab Black sandstone
			Locality No. 2.		
2	93		0.25	0.011	Grab Reddish-brown sand
2	94		0.024		12" Reddish-brown sand
3	95		0.70	0.69	12" Brown and green sand
4	96		0.1		12" Greenish-gray sand
4A	97		1.5	3.21	Grab Yellow sandstone
4B	98		0.13		Grab Reddish-brown sand
5	99		0.037	0.021	12" Gray sand
6	400		0.34	0.16	6" Yellowish sandstone

Pit No. 1 is the discovery locality on the hillside about 150 feet north of the main road. Locality No. 2 is a group of eight low hills known as Poison Buttes through which the main road winds. The samples from locality 2 were collected from seven pits dug near the tops of five of the hills. Uranophane, $Ca(UO_2)_2Si_2O_7 \cdot 6H_2O$, has been identified as the principal uranium mineral from both of these localities.

The occurrence of uranium here is significant because it indicates the possibility that additional uranium deposits may be present in the Browns Park formation and possibly also in the underlying formations unconformably overlapped by the Browns Park in Poison Basin and adjacent areas.

South Dakota

Black Hills, South Dakota
by G. B. Gott, L. R. Page, and R. S. Jones

Areal mapping

Approximately 65 square miles have been mapped at a scale of 1:7,200 in the Edgemont NE, Edgemont, Minnekahta, and Flint Hill quadrangles (fig. 8). About 3 square miles were mapped at 1:20,000 along the Cambrian-pre-Cambrian contact in the Harney 3 SE and 3 SW quadrangles. Mapping of this limited area indicates that the greatest density of uranium occurrences is marginal to the steepest dips of the ore-bearing beds and that the larger deposits are localized in alternating sandstones, siltstones, and mudstones. This suggests that structure and variation between permeable and impermeable lithologies of the host rocks are controlling factors in the localization of carnotite.

The most pronounced structural feature in the area is the Chilson anticline, a southward-plunging anticline superimposed on the Black Hills uplift. Superimposed upon the west flank of this anticline is a structural terrace that produces a peculiar step-like arrangement of gently and steeply dipping beds. Several deposits have been found at or near the abrupt changes in dip bordering the structural terrace. The combination of relatively flat-lying and steeply dipping beds suggest possible underlying intrusives although the structure may have resulted from some poorly understood type of compressive folding.

Numerous small faults with as much as 70 feet of movement have been found, but are not known to have a direct relationship to the uranium deposits.

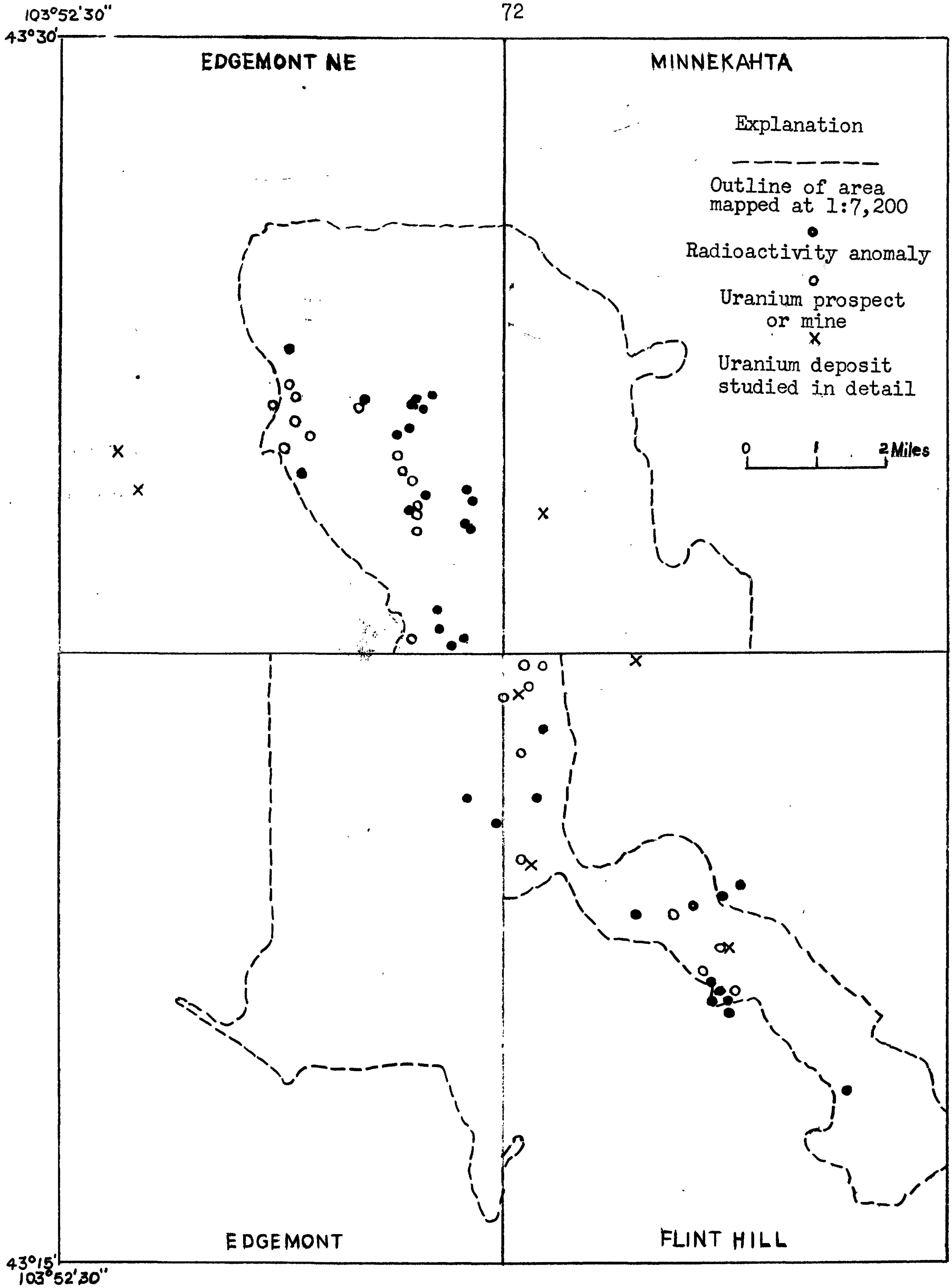


FIGURE 8.--INDEX MAP OF AREAS MAPPED AND DEPOSITS STUDIED, JUNE TO NOVEMBER 1953, FALL RIVER CO., S. DAK.

Widespread but small-scale collapse structures, probably caused by solution of pre-Jurassic rocks, are also present. The movement of soluble calcium or potassium salts, as a result of the solution process, may be of geochemical significance in the study of the uranium deposits.

Several small radioactivity anomalies of 0.02 mr/hr or greater are shown on fig. 9. Additional radioactivity work would probably disclose other anomalies.

In the mapping it has not been possible to reconcile the original definition of the boundaries of the Lakota, Fuson, and Fall River formations with the rocks as they are exposed. Although these formational names are used in the current mapping program to designate arbitrarily units of the Inyan Kara group, it seems clear that a redefinition will eventually be necessary.

Detailed studies

Detailed studies were made of 8 uranium properties: the Lion group, Sheep Canyon, Pabst No. 3, Virginia C, Accidental No. 1, Roadhog 3A, and Cycad-Mattias Peak in Fall River Co., and the Pass Creek area near Dewey, Custer Co.

Although minute quantities of uraninite were identified by X-ray in a drill core from the Lion group, most of the deposits primarily contain carnotite associated with (a) Iron- and manganese-rich carbonate-impregnated sandstone (Lion No. 4, Pabst No. 3), (b) ferruginous sandstone (Lion No. 7, Accidental No. 1, Pabst No. 3, Pass Creek area), (c) silicified sandstone (Pabst No. 3), (d) closely spaced joints (Sheep Canyon, Cycad-Mattias Peak, Lion Group, Pabst No. 3), and (e) abundant shale partings (Virginia C, Roadhog 3A, Sheep Canyon). Investigations at these properties involved

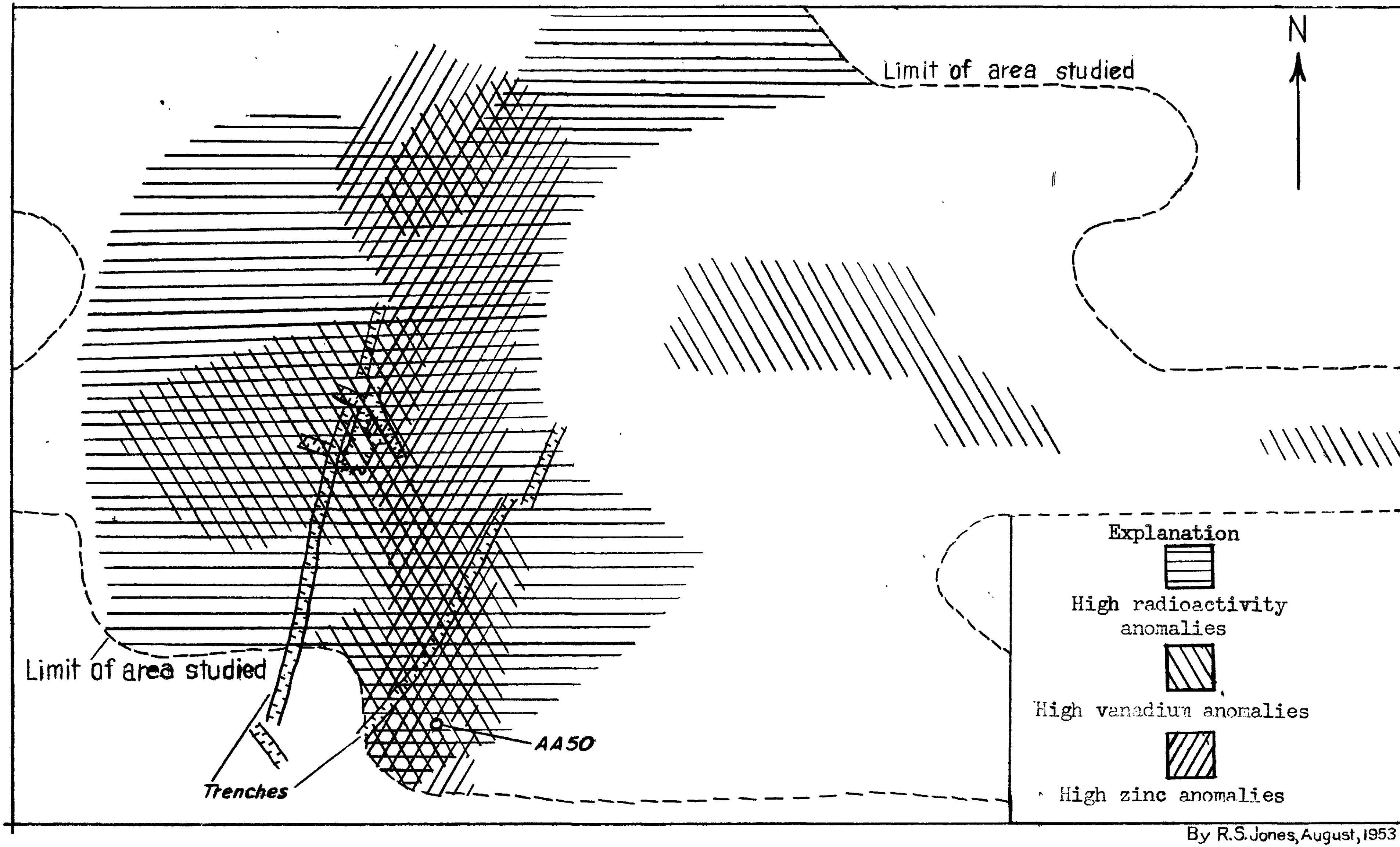


FIGURE 9.—RADIOACTIVITY, VANADIUM, AND ZINC ANOMALIES AT THE LION NO. 4 TRENCHES

mapping at scales of 1:240 to 1:2,400, sampling, and application of geochemical, geobotanical, radioactivity, and petrographic techniques.

Most of the carnotite deposits are associated with ferruginous sandstone, one variety of which is a useful criterion for delineating uranium-bearing areas. This variety is a distinctive pinkish-red sandstone that occurs as a halo partly, or entirely, surrounding carnotite-bearing sandstone and its presence is sufficient to warrant further exploration. Other types of ferruginous sandstone may or may not be associated with uranium. Heavily impregnated red ferruginous sandstones or "iron stone", at the Pabst No. 3 mine appears to represent a halo above favorable ground, but additional exploration is needed to prove this relationship.

Many of the deposits studied appear to be localized in areas where the rim rock weathers into joint blocks spaced 1 to 3 feet apart. Master joints controlled deposition of a major part of the carnotite (as at the Lion group). Where these joints cross shale partings, as in the Sheep Canyon deposits, carnotite may be deposited laterally from the joints below a shale layer. The joints and shale partings also control deposition of other metals such as V, Mn, As, Zn, Pb, and Cu. Highly fractured areas are favorable ground for exploration, but vertical drilling may not prove satisfactory for finding high-grade ore, because the tabular bodies of such ore are nearly vertical.

Extensive studies were made with scintillation detectors of low-level radioactivity. The background count on the sandstones of the Inyan Kara group was determined as less than 0.01 mr/hr. A line representing this amount of radioactivity was found in several areas to include all known deposits as shown in fig 10, map of the Cycad-Mattias Peak mine. Higher levels of radioactivity, such as .02 mr/hr, were outlined inside the .01 mr/hr line and apparently pinpointed additional deposits, some of which have been mined. As other rock types have different radioactivity backgrounds, the level of radioactivity that can be considered anomalous varies with the lithology. On the theory that the radioactivity measured is the result of movement along joints and bedding planes outward from carnotite deposits, low-level anomalies would indicate areas favorable for shallow drilling (probably less than 40 feet). Further research on relating surface anomalies and geology to the results of deep drilling may make it possible to use this method to find ore in lower horizons - perhaps as much as 300 feet in depth.

Geochemical and geobotanical studies were made in favorable areas. The geochemical investigations were found to be quicker and less costly, as well as giving more complete coverage. Soil sampling on 100-foot grids combined with scintillation counter measurements outlines anomalies that may be halos over uranium deposits. The soil samples were analyzed for V, Pb, Cu, and Zn in the field and for as many as 15 metals in the laboratory using rapid semi-extraction methods of analyses.

Vanadium probably is the most useful metal for indicating areas favorable for uranium deposits. The distribution of zinc appears to be somewhat less useful. By a method of rapid field analysis for vanadium devised by the Survey, soil samples were found to contain as much as 0.5 percent vanadium and anomalous areas could be readily defined. Field analyses were also made to determine the distribution of vanadium along joints and within uranium deposits.

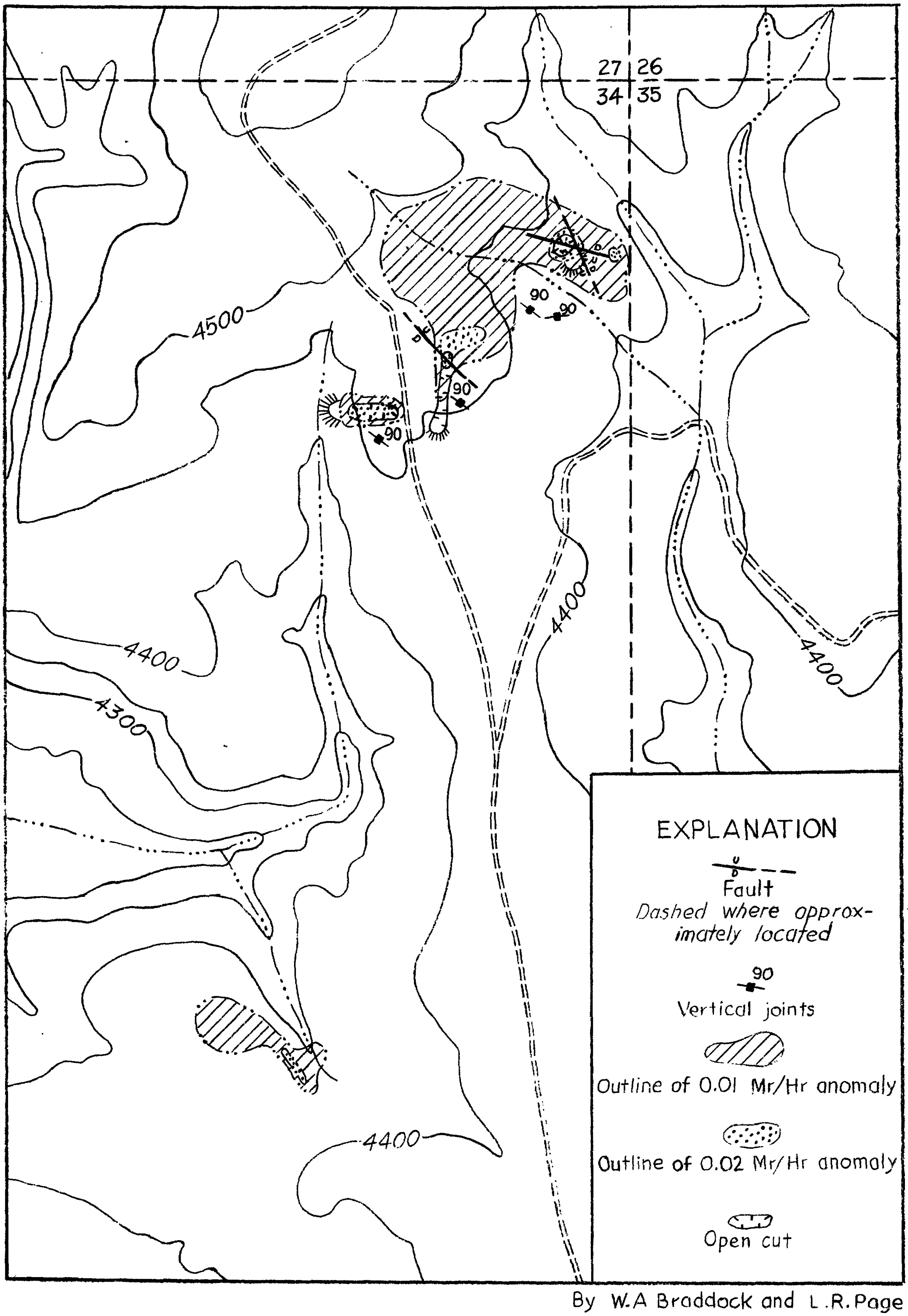


FIGURE 10.--RADIOACTIVITY ANOMALIES, CYCAD-MATTIAS PEAK AREA, FALL RIVER CO., S. DAK.

600 0 600 1200 Feet

A cold dithizone extraction method for Zn, Pb, and Cu combined was used in the field. Blue-black joints gave higher combined Zn, Cu, and Pb values than soils, the soils yielding very low values ranging from no detected metals up to 0.6 micrograms detected as Zn. The anomalies obtained by the dithizone method for combined Zn, Cu, and Pb do not occur in the same place as zinc anomalies (fig. 9) obtained by other methods of chemical extraction.

Zinc is concentrated along the blue-black, iron-bearing joints; at the contact between siltstone and sandstone, and shale and sandstone; and in reaction rims around small carnotite bodies. At the Lion group 20 parts per million of zinc were detected in a small ore body. The black reaction rim around the ore body contained 100 ppm, and the surrounding sandstone 40 ppm. Most sandstones in the area contain less than 20 ppm. These reaction rims have been seen also at the Pabst No. 3 property. A somewhat similar zinc distribution has been noted in the Colorado Plateaus area (TEI-278, p. 29).

Figure 9 shows the radioactive, vanadium, and zinc anomalies on the Lion No. 4 claim where small amounts of carnotite are exposed in shallow bulldozer trenches. Within the radioactivity anomaly there are high zinc and vanadium anomalies.

Geochemical work at the Pabst No. 3 mine consisted of analyzing 22 samples at intervals over 16 feet of alluvium, siltstone, and sandstone stratigraphically above the ore-bearing sandstones and also grid-sampling soils over both the flat dip slope and the canyon wall on which uranium deposits were exposed. The siltstones and sandstones in the vertical section averaged 0.01 percent V; the highest analysis was 0.06

percent V. The content of V in the alluvium was 0.15 percent at the surface and decreased downward to 0.01 percent at the first siltstone. Vanadium (as much as 0.5 percent) and radioactivity (over 0.1 mr/hr) anomalies were found at several places on the surface in the area studied. Their evaluation in terms of uranium must await further exploration.

Geobotanical studies include (1) identification of about 150 species of plants, (2) collection (Rader and Frost) of about 200 samples of pine, juniper, and other plants for background studies of uranium and other metal content, and (3) collection of about 50 samples of plants from areas of detailed soil-sampling for comparison of metal content of plants with soils. This work substantiates Helen Cannon's conclusion (TEM-163) that uranium indicator plants are probably absent in this area and that absorber plants, such as pine, are most useful in outlining areas favorable for uranium deposits where pines grow. Pine trees are found, however, on less than 50 percent of the area underlain by outcropping, ore-bearing Inyan Kara sediments, and no plant has been found in the area where the pine trees do not grow that can be used in prospecting for uranium.

Radioactivity was observed in two spring waters in Sheep Canyon, indicating present movement of radioactive elements. Further evidence of movement of radioactive elements is found in the presence of radioactive bones (Pleistocene?) in soil filling fractures that cut the carnotite deposits on the Pictograph claim. Equilibrium studies of a uraniferous opal coating on sand grains in a Red Canyon deposit suggests that this uranium has also been deposited at a relatively recent date.

Cedar Canyon area, Harding County, South Dakota
by J. R. Gill

Carnotite in the tuffaceous sandstones of the Chadron formation of the White River group (Oligocene) in the southern part of Slim Buttes was discovered in March 1953 (TEI-330). Since that time a geologic map of the southern part of Slim Buttes on a scale of 1:31,680 and a detailed topographic map of the carnotite deposit on a scale of 1:2,400 have been prepared. A report describing the occurrence will be transmitted in January.

White River Badlands
by G. W. Moore

Secondary uranium minerals were discovered July 28, 1953, in sandstone channels in the Chadron formation of Oligocene age in the White River Badlands, Pennington County, South Dakota. Mineralization is also present in thin freshwater limestone beds in the Chadron formation and in groundwater-deposited chalcedony veins in the overlying Brule formation, also of Oligocene age. The uranium mineral in the sandstone has been identified as uranocircite; that in the limestone has been tentatively identified as tyuyamunite or metatyuyamunite. The uranium mineral in the chalcedony veins, which occurs as a yellow efflorescent coating on the outer surfaces of the half-inch veins, has not yet been determined. Assay data is as follows:

Sample No.	Location	Material	Type of sample	eU%	U%
1	Sec. 31-3S-13E	Sandstone	Grab	0.12	0.22
2	Sec. 31-3S-13E	Sandstone	1.0' channel	.20	.25
3	Sec. 36-3S-12E	Limestone	Grab	.017	.023
4	Sec. 36-3S-12E	Chalcedony vein	Grab	.007	.008
5	Sec. 31-3S-13E	Chalcedony vein	Grab	.010	.013
6	Sec. 7-4S-13E	Chalcedony vein	Grab	.015	.013

The uranium minerals occur principally in a sandstone channel about 8 feet thick which is 12 feet below the top of the Chadron formation in the NE$\frac{1}{4}$ sec. 31, T. 3 S., R. 13 E. The most intense mineralization is in the lower 2 feet of the channel, directly above a thick, impermeable bentonite bed. It is thought that the uranium was derived from overlying mildly radioactive tuffaceous rocks of Oligocene and Miocene age, and that the mineralization was effected by downward and laterally moving ground-water.

About 12 square miles, including all of the known areas of uranium mineralization, have been mapped at a scale of 1:12,000. Geologic investigations were concluded September 5, 1953, and a report on the area is now in preparation.

New Mexico

Guadalupita
by C. M. Tschanz

The copper and uranium deposits in the Coyote district, near Guadalupita, occur in lenticular shale, sandstone, arkose, and limestone beds in the lower 2500 feet of the Sangre de Cristo formation, of Pennsylvanian and Permian (?) age. Figure 11 shows the general geologic relationships and the location of most of the mineralized zones. All but one of the known deposits (fig. 11, locality 7) are in a narrow belt of steeply dipping, upturned to overturned, sediments. Several mineralized zones are associated with fossiliferous, marine beds (fig. 11, locality 1 and area G; fig. 12, area B). Although the Sangre de Cristo is predominantly a "red bed" unit, all the known deposits in this area are in gray, green,

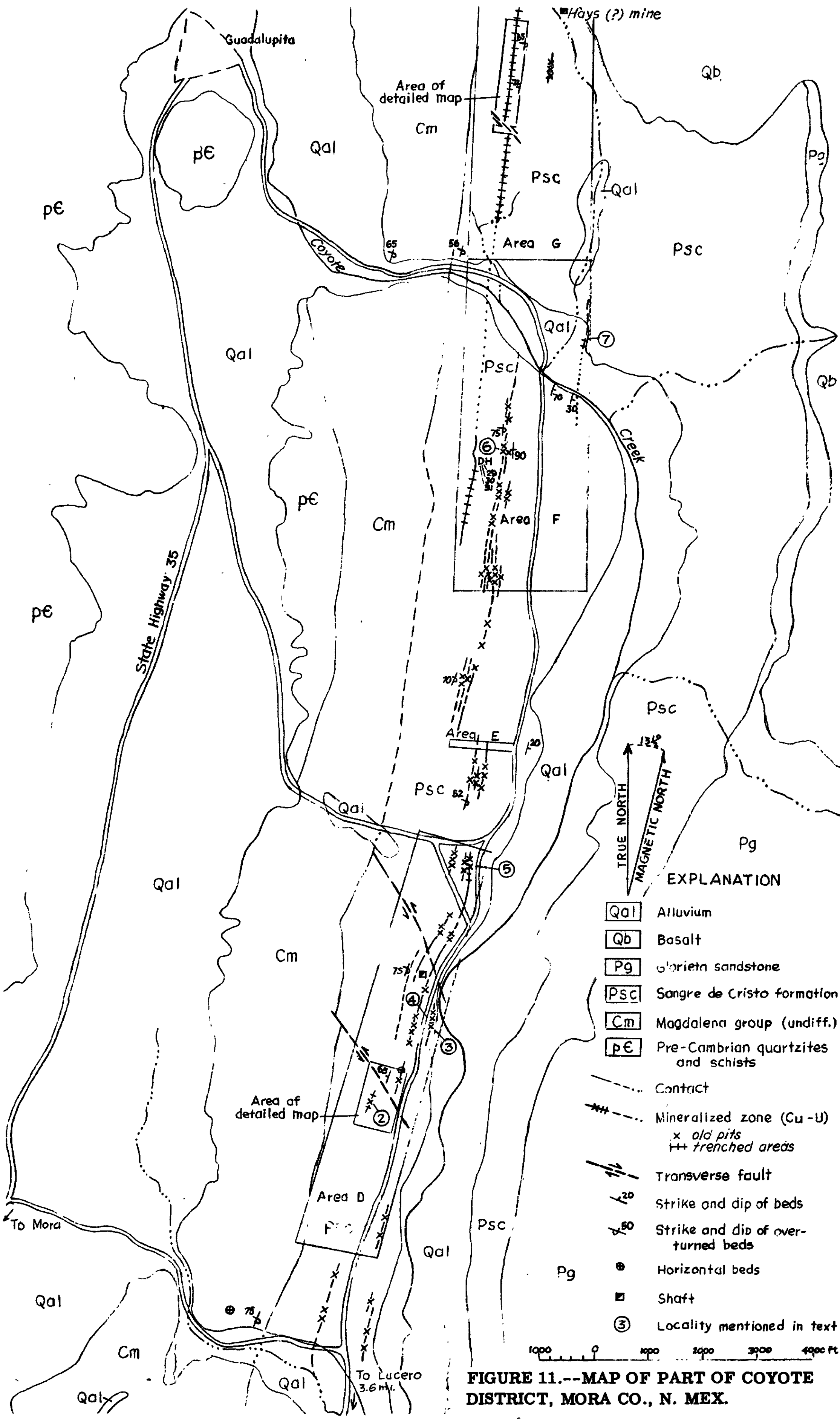


FIGURE 11.--MAP OF PART OF COYOTE DISTRICT, MORA CO., N. MEX.

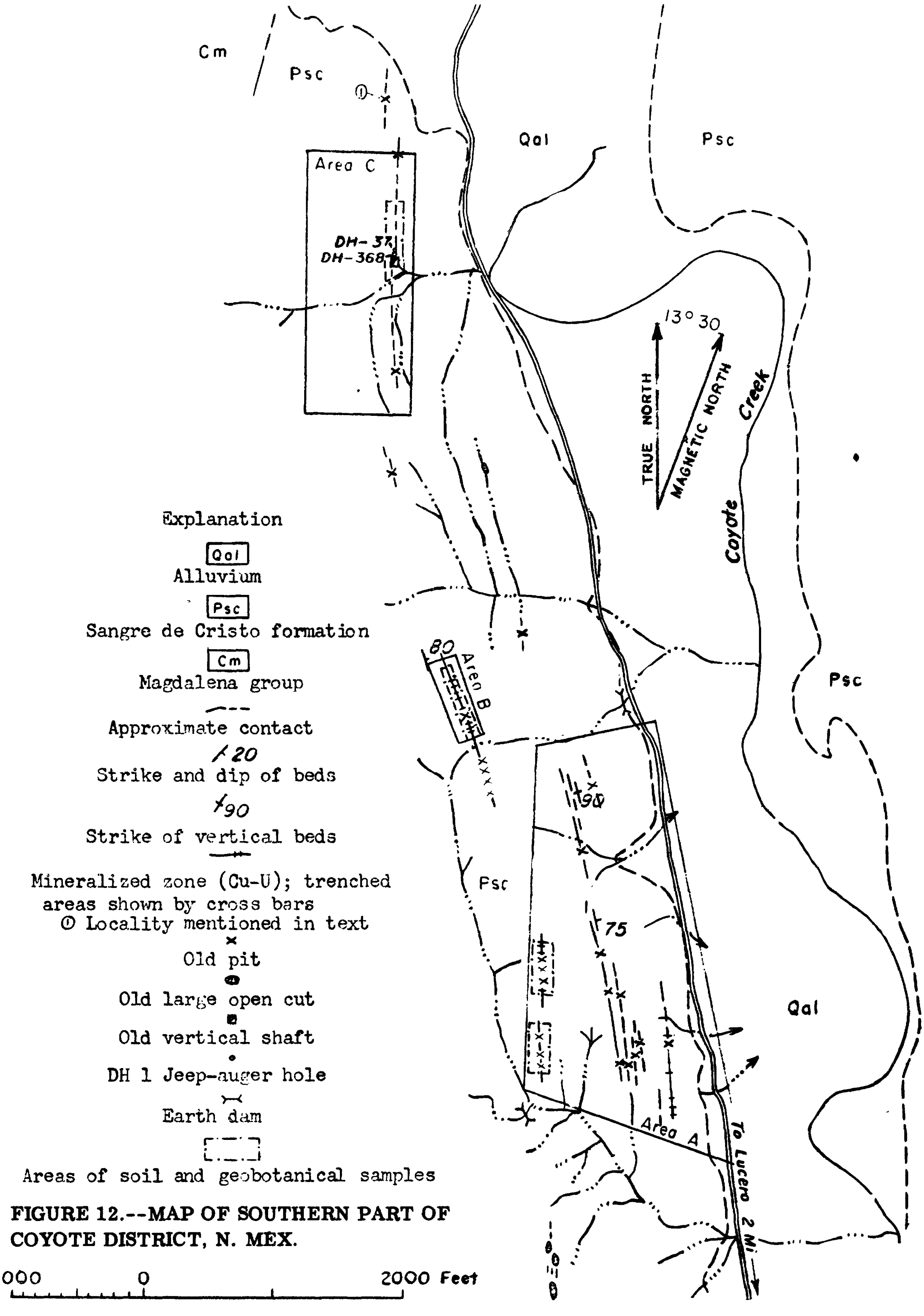


FIGURE 12.--MAP OF SOUTHERN PART OF COYOTE DISTRICT, N. MEX.

dark gray, or yellow-brown beds. At least 7 zones are present; they are from one to 7 feet thick with an average of 2 feet.

Both copper and uranium are more abundant in the more carbonaceous sediments. Sooty and coaly carbonized plant remains are commonly present and either type may be radioactive. Recognizable twigs and stems occasionally are replaced by chalcocite and minor amounts of covellite, bornite, pyrite, and, in one instance, uraninite. Metatyuyamunite occurs at 3 localities (fig. 11, localities 2, 4, and 5) as a powdery coating or dissedminated grains in medium-grained, arkosic sandstone and in a carbonized log in locality 3. Minute grains of chalcopyrite, and two unidentified metallic minerals occur in highly radicactive, pink, arkosic sandstone at locality 7.

The work to date has been divided into 6 phases: detailed mapping, trench mapping, trenching, drilling, soil and geobotanical sampling. All mapping is on a scale of 1 inch to 200 ft except for 2 small areas mapped at 1 inch to 50 ft. The outline of the mapped areas, totaling 1.5 square miles, is shown on figures 11 and 12.

The mapping clearly shows the discontinuous nature of the mineralized zones and the lenticular shape of the sedimentary units. The copper and uranium deposits are usually more restricted than the enclosing rock type, particularly in the coarser-grained sediments. In sand-sized sediments, the values are spotty and the deposits are small.

The west mineralized zone in northern part of fig. 11 is fairly continuous and is not subject to sudden lithologic changes. (See fig. 13). The grade of the mineralized material varies from place to place but the zone is mineralized to some extent throughout its traceable length. The

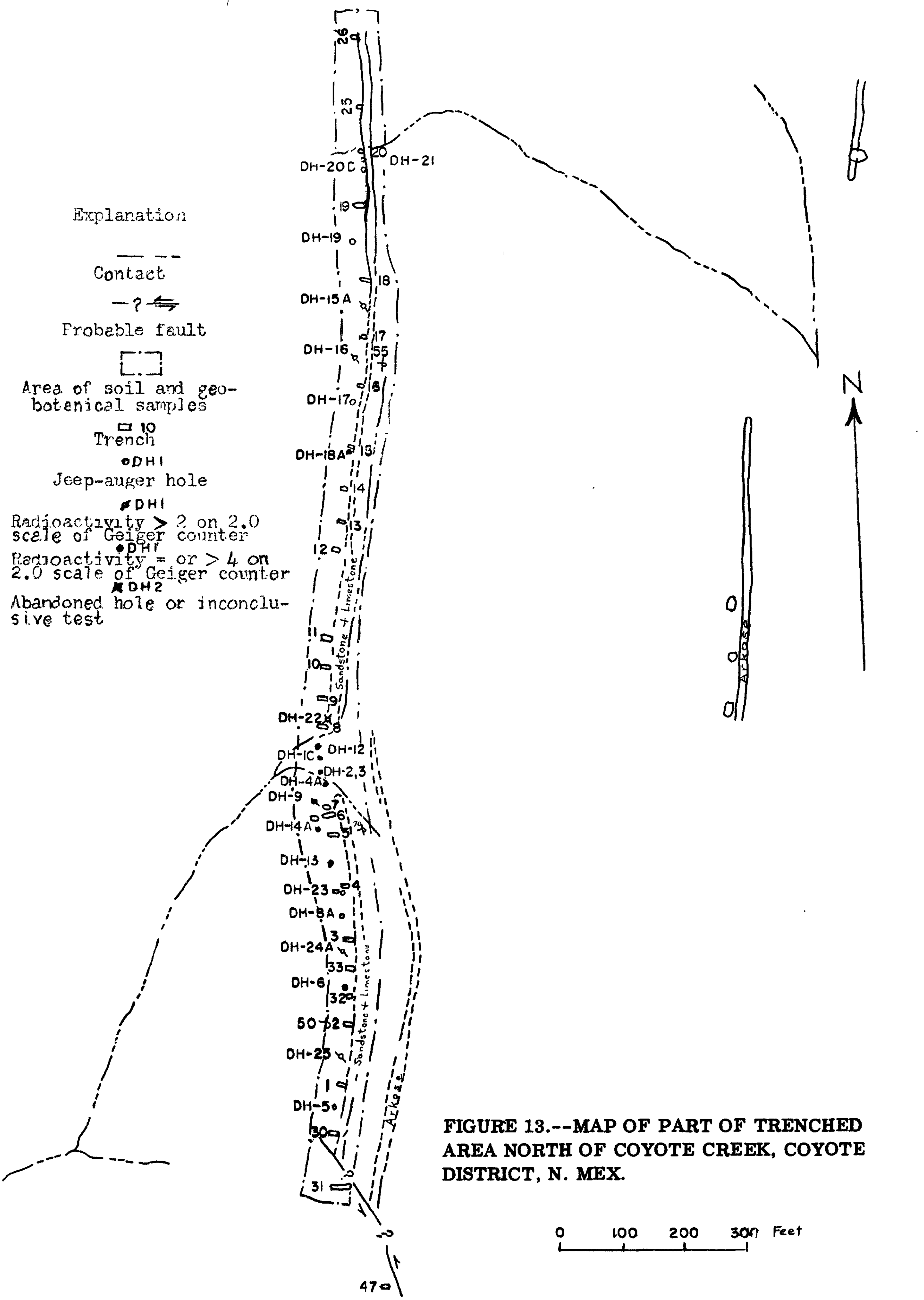


FIGURE 13.--MAP OF PART OF TRENCHED AREA NORTH OF COYOTE CREEK, COYOTE DISTRICT, N. MEX.

radioactivity is several times as great as that of any other material yet discovered in quantities greater than a few hundred tons. The mineralized material is a yellow-brown or green-brown, micaceous siltstone that usually contains several thin carbonaceous shale seams in the more radioactive parts. It is overlain by a series of thin-bedded sandstones with one or more fossiliferous limestone beds. The siltstone pinches out to the south, being replaced by a brownish locally radioactive sandstone. These relationships can be interpreted as indications that the radioactive siltstone pinches out down dip, thus limiting the depth of the "ore" shoot.

A similar and possibly the same radioactive marine siltstone-sandstone sequence south of Coyote Creek (fig. 11) is more variable in grade and spotty in distribution but the best material is better than that north of Coyote Creek.

The best grade material yet discovered is in the "feather edge" of thin arkosic sandstone at locality 2, fig. 11. (See fig. 14). Metatyuyamunite is visible in the trenches along a 120-foot section of the zone. The grade decreases as the rib thickens northward. Pits to the north and south are only slightly radioactive.

Spotty, highly radioactive material was discovered 500 feet north of Coyote Creek at locality 7, fig. 11. The best material is a thin, pink arkosic sandstone bed several hundred feet higher in the stratigraphic sequence than any other mineralized zone. It is the only mineralized area known to exist in the west limb of the Jarosa syncline. It is also the only locality here at which chalcopyrite has been seen. No radioactive spots have been found north of this locality, but a local "hot spot" was found on the south bank of Coyote Creek and several moderately radioactive spots have been discovered by trenching between these two localities.

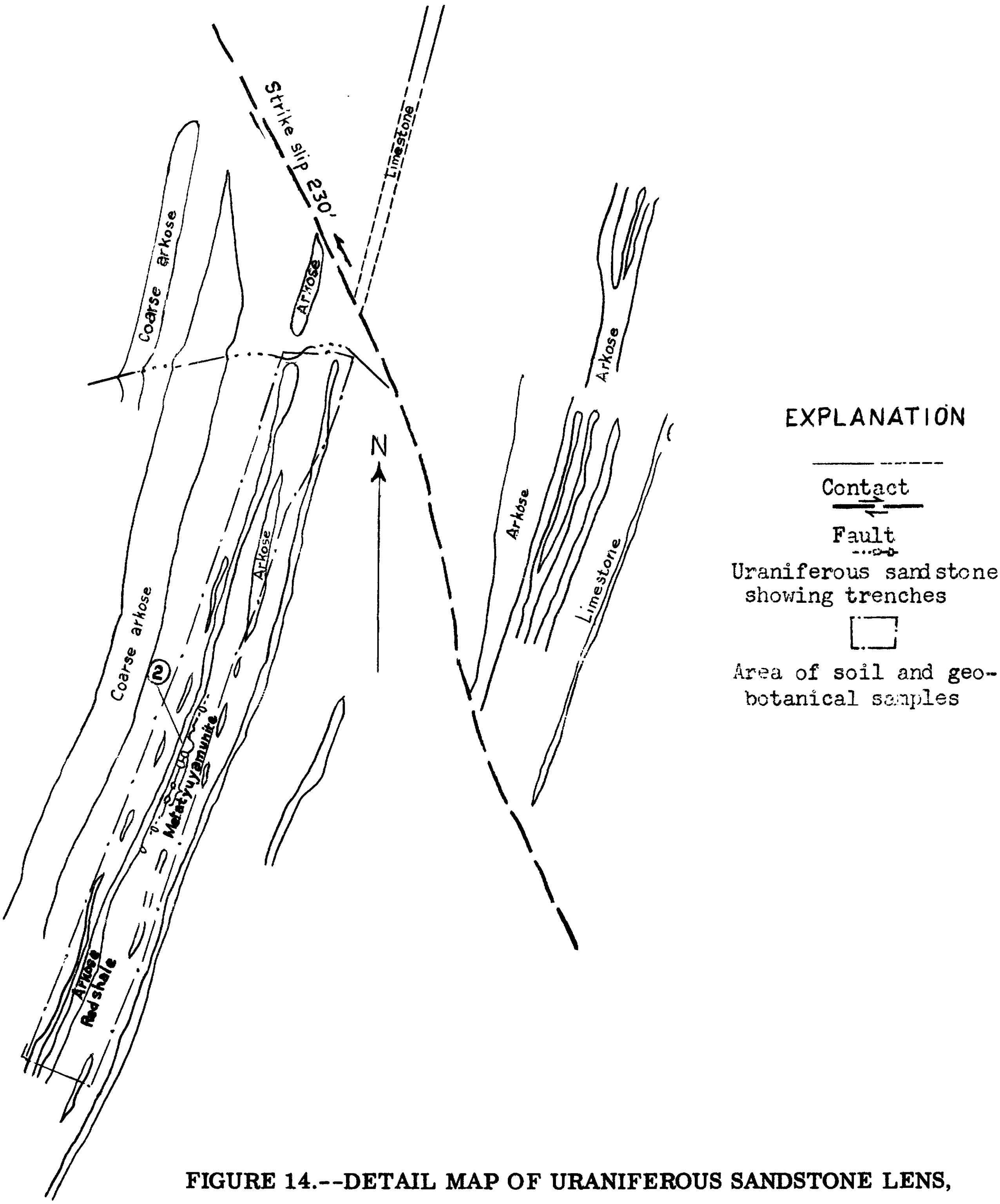
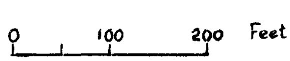


FIGURE 14.--DETAIL MAP OF URANIFEROUS SANDSTONE LENS, COYOTE DISTRICT, N. MEX.



To test the possibility that the uranium content might increase below the leached outcrops, 49 holes totaling 973 feet were drilled with a jeep-mounted auger. The machine can drill only vertical holes and cannot cut through limestones or well-cemented sandstones. Therefore, many holes were abandoned before "ore" was reached. The program, however, is considered a qualified success.

Two holes in area F cut a radioactive copper-bearing black, carbonaceous shale exposed in an old pit at locality 6, fig. 11. Two other holes are on either side of a large, deep pit with many chalcocite nodules, and carbonaceous shale on the dump. These are the only holes that showed visible copper in the cuttings.

In the geochemical prospecting phase of the program, 457 plant samples and 351 soil samples were collected. Copper, lead, and zinc values have been received on 300 plant samples and 130 soil samples. Lead will not be determined in any of the remaining 231 soil samples since the first results indicate that the lead content is negligible. No uranium analyses have yet been made. The higher geochemical anomalies will be trenched. The results of preliminary study of the metal content are as follows:

Table 1.--Copper, lead, and zinc values for high geobotanical samples, Guadalupita, New Mexico

Area	No. samples	Mineral content, ppm				
		Maximum			Average	
		Cu	Zn	Pb	Cu	Zn
A	25	No data				
B	44	300	1600	140	134	969
C	24	No data				
D	70	1500	1600	150	165	721
E	48	200	1000	100	101	430
F	114	280	1600	100	139	572
G	82	280	1600	100	114	501

For all areas except "B", which has a ratio of 7.2, the Zn/Cu ratio for the different areas ranges between 4.1 and 4.8. Area B also has a high lead content.

Table 2.--Copper, lead, and zinc content of high soil samples

Area	Number	Number of samples (ppm) 100Cu	100Zn	20Pb	Maximum Cu	Zn	Average Cu	Zn
D*	46	11	3	2	700**	100	<74	54
E	82	7	10	1	250	100	<33	60

* Locality 5, fig. 11, traverse "B" at right angles to strike.
** This sample and another probably contaminated from dump.

Geobotanical samples were collected from 3 varieties of juniper, ponderosa pine, pinon, and scrub oak. The species distribution of 96 samples containing at least 200 ppm Cu. or 1000 ppm Zn, or 100 ppm Pb is as follows:

Table 3.--Species distribution of high geobotanical samples

Metal	Number of samples distributed by species: Pinon	Ponderosa	Juniper	Scrub oak
Cu	25	3	0	1
Zn	32	35	3	0
Pb	4	7	4	3
Cu-Zn	7	2	0	0
Cu-Pb	0	0	0	1
Zn-Pb	2	3	1	0
Cu-Pb-Zn	2	1	0	0

It is apparent that the pines preferentially absorb zinc from the soil because the content of the plant ash is much higher than in the soil. The copper content is more nearly constant. The high Zn/Cu ratio in area "B" may reflect the fact that most geobotanical samples were

Ponderosa rather than reflecting a high zinc content of the "ore". However, "red bed" copper deposits elsewhere in New Mexico contain several percent zinc.

Field work will be recessed December 15, 1953. The only exploration planned for the new field season is a limited amount of trenching on promising anomalies resulting from the soil or geobotanical sampling programs.

Field-check of the maps and study of questions raised by the winter's laboratory investigations are planned for early spring and it is expected that all work will be completed before the end of the fiscal year.

URANIUM IN LIMESTONE

Miller Hill area, Carbon County, Wyoming
by J. D. Vine and G. E. Prichard

Geologic studies of the Miller Hill area consisted of geologic mapping of about 150 square miles in Ts. 16 and 17 N., Rs. 87 and 88 W. (fig. 15) and detailed radioactivity studies of a uranophane-bearing limestone bed over an area of about 320 acres (see fig. 16). Test pits were dug at eight localities for detailed sampling.

The Browns Park (?) formation, which in the Miller Hill area is at least 800 feet thick, contains higher than normal radioactivity erratically distributed over a wide area. Unusually high radioactivity most commonly occurs where the limestone is fractured and brecciated and is associated with secondary silica in the form of chalcedony and opal. No above normal radioactivity was found in any of the underlying formations.

The most favorable host rocks for uranium are limestone and calcareous sandstone beds 5 to 15 feet thick 200 to 450 feet above the base of the Browns Park (?) formation. About 50 radioactive localities throughout the area have been studied (see fig. 15) and 200 samples, including about 50 water samples, were submitted for analysis. Some of these localities were detected by airborne radioactivity surveys made by the Geological Survey and by AEC.

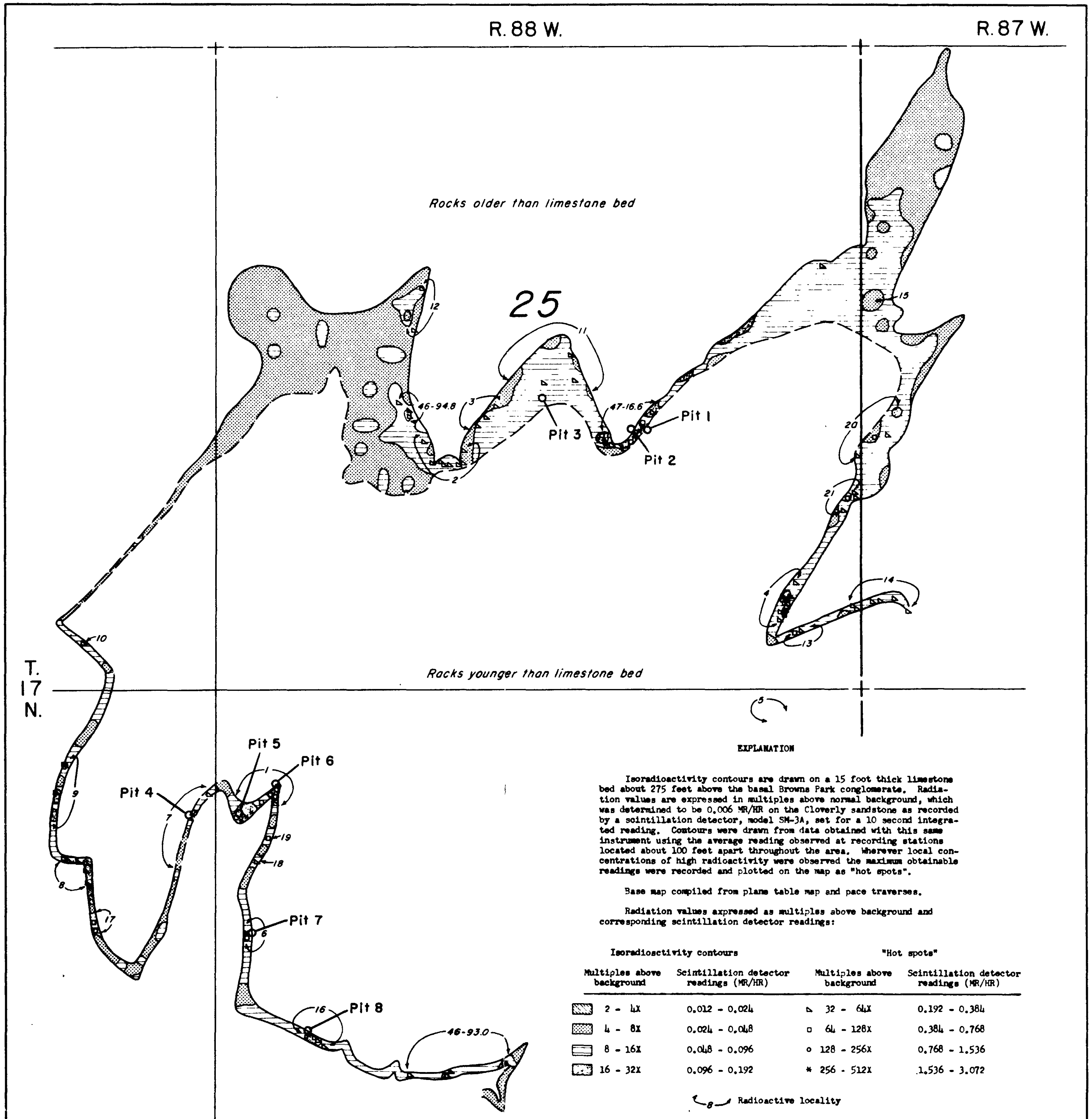
Uranophane, $Ca(UO_2)_2Si_2O_7.6H_2O$, has been tentatively identified as the principal uranium mineral.

Eight test pits were dug from 4 to 8 feet into the limestone in cooperation with the AEC. Analyses of select grab samples collected from the top few inches of limestone at several of the pits are shown below:

Pit No. (fig.16)	Field No.	Lab. No.	eU (percent)	U (percent)	Description
2	VW3-72	D-97423	0.39	0.39	Chalcedonic limestone with uranophane
4	68	D-97421	0.17	0.12	" "
5	71	D-97422	0.23	0.18	" "
7	65	D-97418	0.32	0.24	" "
8	66	D-97419	0.25	0.22	" "
8	43	D-94719	0.36	0.40	" "

Geiger counter readings indicate that only about the upper foot of limestone in each pit is significantly radioactive.

The uranium is thought to be of volcanic origin and was once disseminated throughout the tuffaceous sandstones of the Browns Park (?) formation. Subsequent groundwater migration redistributed the uranium along with free silica and concentrated them at or near the top of the relatively impermeable limestone and lime cemented sandstone units.



EXPLANATION

Isoradioactivity contours are drawn on a 15 foot thick limestone bed about 275 feet above the basal Browns Park conglomerate. Radiation values are expressed in multiples above normal background, which was determined to be 0.006 MR/HR on the Cloverly sandstone as recorded by a scintillation detector, model SM-3A, set for a 10 second integrated reading. Contours were drawn from data obtained with this same instrument using the average reading observed at recording stations located about 100 feet apart throughout the area. Wherever local concentrations of high radioactivity were observed the maximum obtainable readings were recorded and plotted on the map as "hot spots".

Base map compiled from plane table map and pace traverses.

Radiation values expressed as multiples above background and corresponding scintillation detector readings:

Isoradioactivity contours		"Hot spots"	
Multiples above background	Scintillation detector readings (MR/HR)	Multiples above background	Scintillation detector readings (MR/HR)
2 - 4X	0.012 - 0.024	32 - 64X	0.192 - 0.384
4 - 8X	0.024 - 0.048	64 - 128X	0.384 - 0.768
8 - 16X	0.048 - 0.096	128 - 256X	0.768 - 1.536
16 - 32X	0.096 - 0.192	* 256 - 512X	1.536 - 3.072

Radioactive locality

FIGURE 16.--ISORADIOACTIVITY CONTOURS ON A LIMESTONE BED IN THE BROWNS PARK FORMATION MILLER HILL AREA, CARBON COUNTY, WYOMING

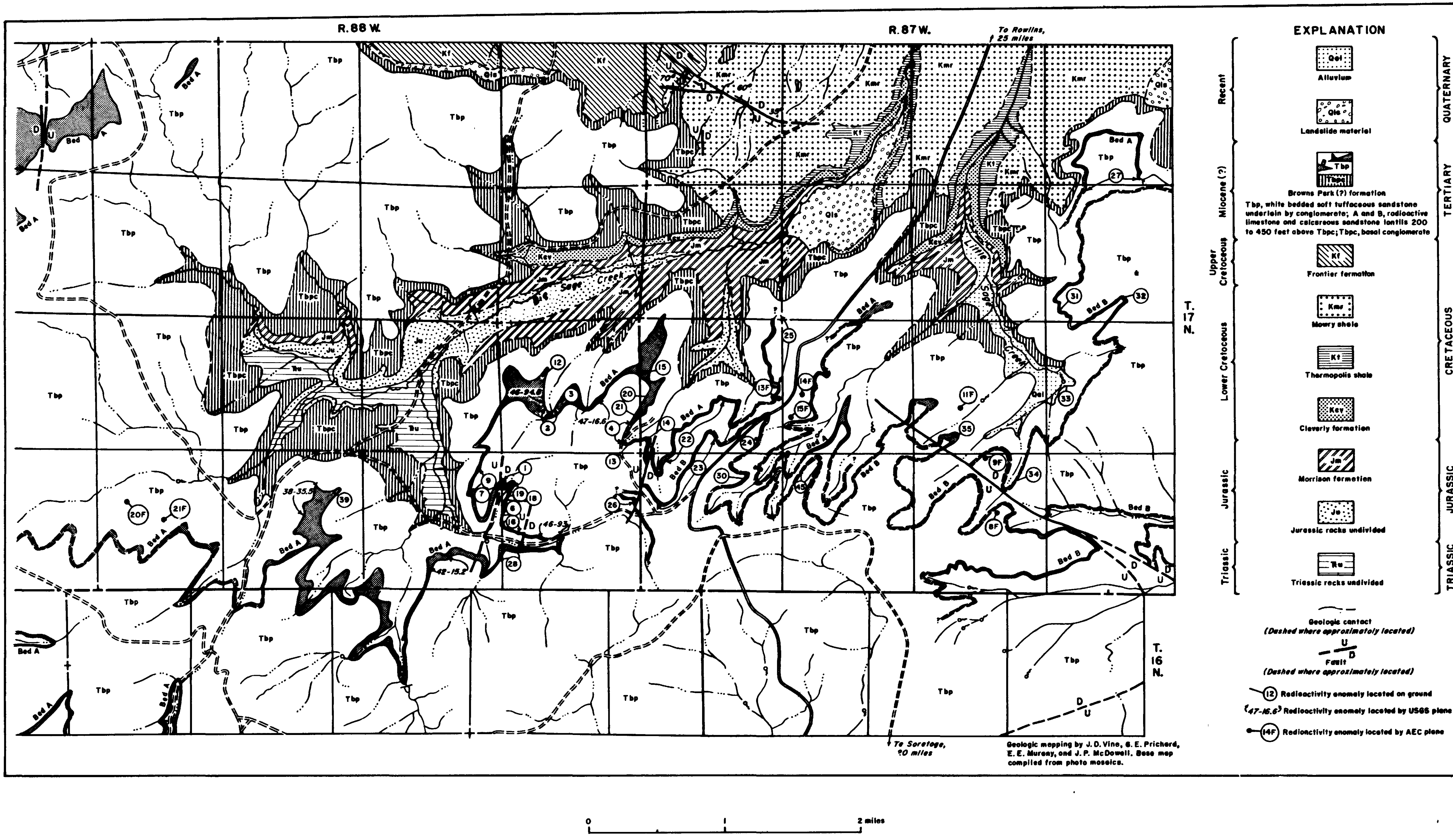


FIGURE 15--GEOLOGIC MAP OF THE MILLER HILL AREA, CARBON COUNTY, WYOMING

URANIUM IN VEINS, IGNEOUS ROCKS, AND RELATED DEPOSITS

General geologic studies

Zonal relations of uranium deposits in metalliferous districts by S. R. Wallace and R. H. Campbell

In the spring of 1953 a radioactivity reconnaissance of the Gold Hill district, Boulder County, Colo., was made in an effort to establish the position of uranium occurrence in the sulfide-telluride zonal pattern first reported by B. F. Leonard (TEI-330). A preferred position of the uranium within the zoning sequence has not yet been established but five localities showing visible uranium mineralization and a number of radioactivity anomalies were discovered. Analyses show that all five localities that contain uranium minerals and five of the radioactivity anomalies that show no visible uranium minerals contain 0.1 percent U or better.

The field program was recessed on July 1 and the activities of the project were curtailed accordingly. About five weeks were spent with field parties in the Idaho Springs and Central City districts gathering data for comparison of these areas with the Gold Hill district. Additional work done includes:

(1) Additional sampling in the North Gilpin County, Colo., district to check the zonal distribution of metals.

(2) Examination and some underground mapping of the Goldsmith Maid prospect in the Gold Hill district.

(3) Compilation of data on districts in the Front Range mineral belt suggesting that the Jamestown district and the Montezuma-Breckenridge area exhibit zonal patterns in which uranium occupies a preferred position.

A report presenting the results of the zoning studies to date is about 20 percent complete, and will probably be submitted before the end of fiscal year 1954.

Frequency distribution of uranium with relation to enclosing rock type
by J. W. Adams and F. Stugard, Jr.

The investigation of the possible control of uranium deposition by wall rocks was continued during the reporting period by field and laboratory studies. Field work was done in the Golden Gate Canyon area (TEM-154, revised for USGS Circular 320) near Denver, where a definite correlation was found between the occurrence of uranium and the type of wall rock involved. As shown on the accompanying map (fig. 17), the uranium occurrences and significant radioactivity anomalies are almost exclusively confined to narrow hornblende gneiss layers in a metamorphic complex that locally is predominantly quartz-biotite gneiss. Northerly-trending faults appear to have been the channelways for the uranium-bearing solutions.

Although the work to date has confirmed the lithologic correlation of the radioactive deposits with one rock type, it is not known as yet why the hornblende gneiss is the preferred host rock for the uranium minerals. An attempt to answer this question is being made by 1) mineralogical and chemical studies of the "favorable" and "unfavorable" rocks of the area, and 2) by studies of the paragenesis of the minerals in the ore assemblage.

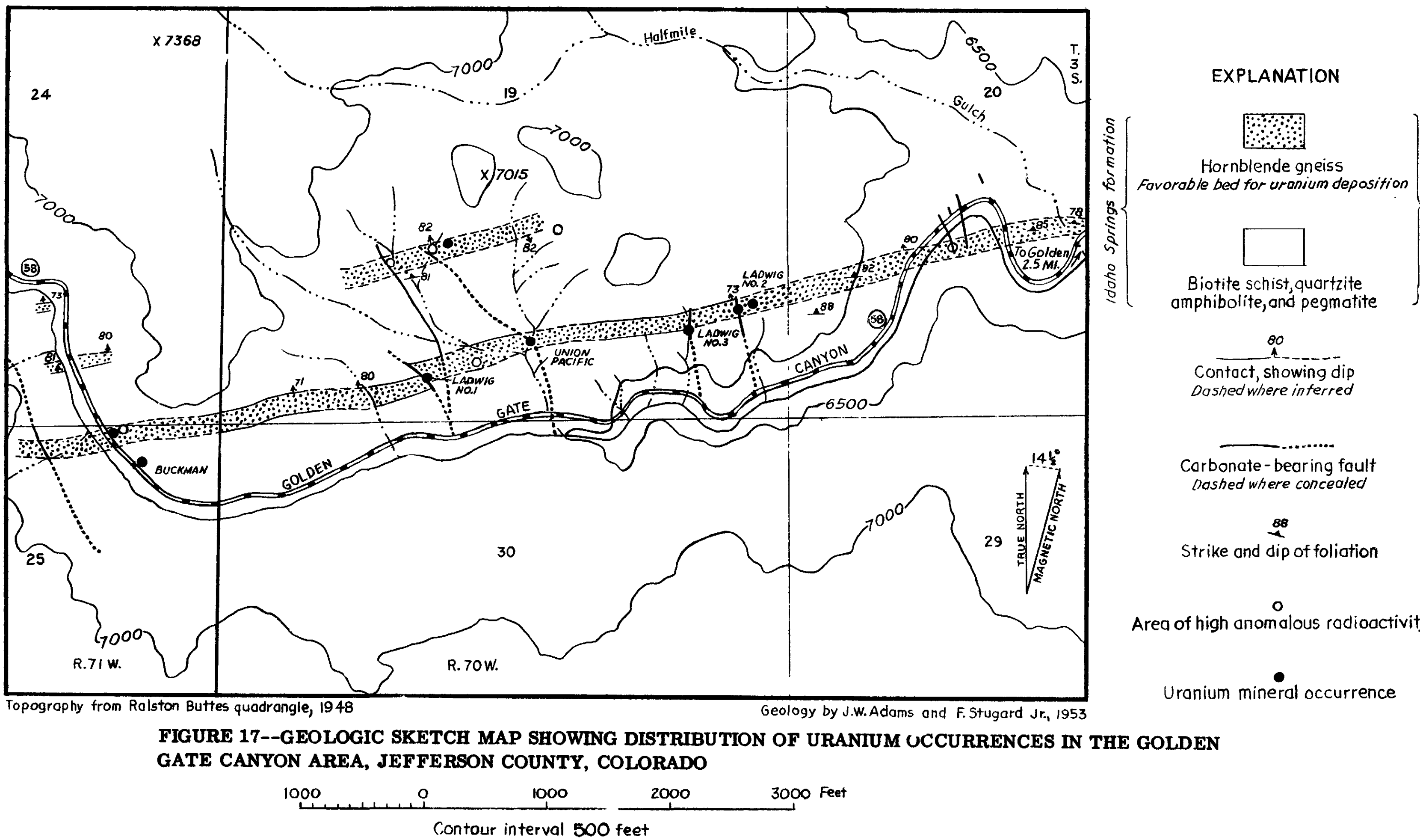


FIGURE 17--GEOLOGIC SKETCH MAP SHOWING DISTRIBUTION OF URANIUM OCCURRENCES IN THE GOLDEN GATE CANYON AREA, JEFFERSON COUNTY, COLORADO

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

Field work during this period consisted of field examination and sampling of about 140 bodies of volcanic rock, mostly of glassy or partly glassy texture, and nearly all of rhyolitic or dacitic composition, where the composition was previously determined. Areas sampled are widely distributed over Utah, Nevada, southern Idaho, Wyoming, Montana, Washington, Oregon, California, Arizona, and Colorado. Some radioactivity examination of the rocks was done in the field with a scintillation counter.

Uranium analyses, and spectrographic determinations for manganese, tin, niobium, lanthanum, beryllium, boron, lead, and zirconium have been received for the samples collected in 1952, and spectrographic determinations of tin, niobium, lanthanum, boron, beryllium, lead, and zirconium for about half the samples collected in 1953. The pattern of distribution of uranium is now based only on samples collected in Utah, Nevada, Oregon, Washington, and California. In these areas it resembles, in a general way, the pattern, based on more samples, for tin, niobium, lanthanum, beryllium, boron, and lead. The uranium pattern suggests a maximum in western Utah and eastern Nevada, diminishing gradually toward western Nevada and southern California south of the Garlock fault, and perhaps with a secondary minor maximum in the California Coast Ranges. The minima apparently are concentrated in the Sierra-Cascade province. The amounts involved are all small, falling generally in the range of ten-thousandths of a percent, and only occasionally in the thousandths of a percent. Although the patterns of distribution of the other elements (tin, niobium, lanthanum, beryllium, boron, and lead) are similar in a general way to the pattern for uranium, the results from the additional samples taken during

1953 and analyzed this fall suggest that the maximum for many of these elements may be farther north, in the general region of southern Idaho, northwestern Utah, and northeastern Nevada. The meaning of these patterns is not yet clear; it is tempting to correlate the low values for uranium in the Sierra-Cascade province with the scarcity, amounting almost to a complete absence, of uranium deposits in this province. It may, however, be merely a reflection of the lower concentration appropriate to an earlier stage in the differentiation series, leading through dacite to rhyolite. The general resemblance of the pattern for uranium to that for other elements, which, like uranium, are known to be concentrated in pegmatitic rest-magmas suggests that the same physico-chemical laws have been responsible for the concentration of all these elements. As none of the other elements, with the possible exception of lead, characterizes vein deposits of uranium, any similarities in the distribution of vein deposits of uranium and silicic volcanic rocks rich in uranium and these other elements might be explained in several ways. One possible mechanism would be the selective leaching of uranium from the uranium-rich rock by hydrothermal solutions; another mechanism, somewhat speculative, would involve a partitioning of the uranium between the rhyolitic magma, or one ancestral thereto, and a partial magma ancestral to the vein deposits of uranium.

It is expected that, with the receipt of analytical and spectrographic data on the rest of the samples collected during 1953, it will be possible to delineate provincial boundaries, based on the relative amounts of the various trace elements enumerated above. Additional field work in New Mexico and parts of Colorado and Arizona are planned for the spring of 1954.

District studies

Colorado Front Range
(Georgetown - Central City area, Colo.)
by P. K. Sims and others

Introduction

Geologic mapping has been done by four field parties in adjacent areas: Central City district, Dumont-Fall River region, the area extending from Idaho Springs westward to Fall River (Idaho Springs district), and the area east and south of Freeland. Systematic reconnaissance for radioactivity was made in parts of the Central City district. To date about 28 square miles of surface mapping (fig. 13) has been done on scales of 1:6,000 to 1:12,000, and about 85,000 linear feet of underground mapping on scales of 1:120, 1:240, 1:480, 1:600, and 1:1,200 has been completed.

The AEC financed exploration at the Cherokee mine in Pleasant Valley and at the Springdale (Gold Rock) mine, both in the Central City district. The DMEA financed exploration programs at the East Calhoun and German mines. The Cherokee, East Calhoun, and Springdale mines stockpiled small quantities of uranium ore, but there have been no recent shipments from the region.

The principal uranium discoveries during the period are in the Eureka Gulch-Nigger Hill area of the Central City district, where pitchblende and secondary uranium minerals are known at eight localities. Occurrences of secondary uranium minerals at the Two Sisters and R. H. D. mines are in part of ore grade. A report on this area is in preparation.

General geology of area

The ore deposits occupy veins that cut pre-Cambrian metamorphic and igneous rocks and, at places, Tertiary porphyries. The pre-Cambrian

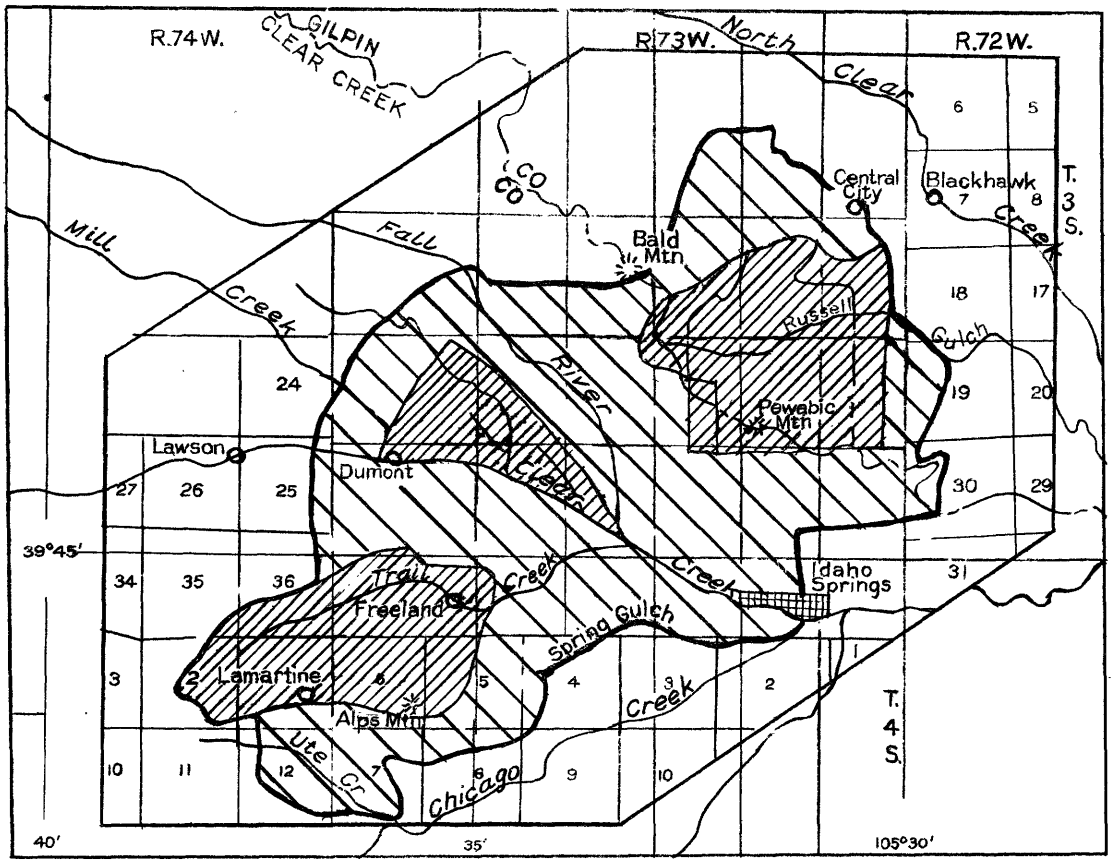
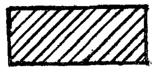


FIGURE 18.--MAP SHOWING OUTLINE OF THE GEORGETOWN-CENTRAL CITY AREA, COLORADO FRONT RANGE

Explanation



Area mapped July-November, 1952

Area mapped June-October, 1953

rocks consist largely of metamorphosed sedimentary rocks of the Idaho Springs formation and granitic rocks. Mafic rocks, in part of intrusive origin, are widespread but not abundant in the region.

The pre-Cambrian rocks were folded by two periods of deformation. The earliest, and dominant, fold system trends about N. 30° E. and is characterized by broad open folding in the northwestern part of the map area (Dumont-Fall River and Central City regions). Southeast of the mouth of the Fall River, however, the rocks are for the most part tightly folded and the folds are overturned to the southeast. Superimposed on the tight folds in this region is a younger fold system, the fold axes of which plunge about N. 55° E. The second fold system is strongly monoclinal; it is characterized by shear type folds and apparently is related to zones of strong cataclasis. The wavelength and amplitude of folds of the younger system appear to increase toward the southeast. The first major axis of the second fold system passes through the town of Idaho Springs.

The Tertiary porphyries (principally monzonite and bostonite) (see TEI-247) form dikes, plugs, and small stocks.

The veins throughout the Georgetown-Central City region belong to two general mineralogic types: pyritic gold and sphalerite-galena. At places the two types overlap to form composite veins. Uranium, where present, is generally in the transition zone between the two types of veins. The vein pattern is complex and varies in some respects from place to place within the region.

<u>Central City district,</u> by P. K. Sims and A. A. Drake

Geologic mapping was done in the area north of Quartz Hill and west of Central City, and in the Gilson Gulch area northward to

Russell Gulch. Systematic reconnaissance for radioactivity was made in the northwestern part of the district.

The uranium occurrences in the Central City district are principally hard, lustrous pitchblende, except in the north slope of Nigger Hill northwest of Central City, where secondary uranium minerals - meta-torbernite, meta-zeunerite, and sparse kasolite - are present. The principal occurrences are in the Quartz Hill-Russell Gulch area, the Eureka Gulch-Nigger Hill area, and an area near Justice Hill. Only the Quartz Hill area has yielded commercial uranium ore.

The uranium minerals occur on two and possibly three vein sets: (1) northeasterly-trending veins, as the Calhoun; (2) easterly-trending veins, as the Wood and Leavenworth; and (3) northwesterly-trending veins, as the Buckley.

Within the district pitchblende occurs both along the main veins and in subsidiary branching fractures which are possibly tension openings. The pitchblende was deposited with the earliest metallic minerals and subsequently was brecciated by movements along the veins. The meta-torbernite (?) in the Nigger Hill area occurs principally in the altered wall rocks adjacent to the vein, and to a lesser extent along the quartz veins. Some meta-torbernite (?) of ore grade has replaced altered mica-quartz-feldspar schists; this occurrence, so far as is known, is unique in the United States.

It is tentatively concluded that the uranium in the Central City district was derived from "local" bostonite magmas, whereas the other metals were derived from a deep, differentiating monzonite magma. The uranium was deposited in open fractures relatively near the source, generally as small, high-grade bodies. The lithology of the wall rocks seems to have had little if any effect on the deposition of uranium, contrary to the situation in most Canadian vein pitchblende deposits.

Idaho Springs district, by R. H. Moench

Detailed geologic mapping of 2.5 square miles was completed between Virginia Canyon, Idaho Springs, Bellevue Mountain, and the mouth of the Fall River; only a small part of this area, however, was examined systematically for radioactivity.

The pre-Cambrian rocks in this area are in tight folds overturned to the southeast; folds belonging to the younger period of pre-Cambrian deformation are superimposed on the early tight folds. In the northern part of the area, however, in the vicinity of Bellevue Mountain, the folds are relatively open, much like those in the Central City region.

Two types of vein structures are present. In the area of open folding where the dips in the pre-Cambrian rocks are gentle, the veins trend northwesterly or westerly and dip 35° to 45° northward; but in the area of tight folding and steep dips, the veins trend northeasterly and dip steeply. Southeast of the first major fold axis of the younger, N. 55° E. fold system (in the town of Idaho Springs) the veins are sparse, weak, and erratic in trend.

The structure of the steeply dipping veins apparently is controlled primarily by the foliation, and at places the axial planes of folds, in the pre-Cambrian rocks. In the central part of the area, however, the strongest veins cut the foliation at a low angle. The tentative vein relations in order of decreasing age, decreasing number of veins, and increasing strength of veins is: N. 60° E. (in foliation), N. 40° E., and N. 20° E. Another set of veins occurs within and parallel to a prominent northwest-trending fault that cuts through the Idaho Springs district and extends into the Dumont-Fall River area.

The mineralogy of the veins in most of the district is predominantly pyrite and quartz. Tetrahedrite (or tennantite) is commonly present. In the central and upper parts of Virginia Canyon and south of Clear Creek, however, many of the veins are composite in character.

A reconnaissance in the northeast-trending zone of quartz-pyrite veins between the mouth of the Fall River and the Stanley mines disclosed four radioactive occurrences: Stanley mines, Laurence L claim, P. J. claim (?), and an unidentified mine 220 feet south of the P. J. claim. These occurrences cannot be evaluated at present; however, samples from the radioactive part of the Stanley vein contain as much as 0.3 percent eU.

Area south and east of Freeland, by J. E. Harrison and J. D. Wells

Surface mapping was extended south and east from the Freeland-Lamartine district (TEI-295) toward Chicago Creek. The veins in the mapped area appear to occur along the axial planes of folds in tightly folded areas and the foliation or contacts between lithologic rock units along the flanks of open folds. A group of flat veins that dip 45° or less to the northwest was mapped in the area between Trail Creek and Clear Creek. These veins carry mostly gold and copper, and appear to be connecting veins between steeper vein systems in tightly folded areas around Freeland to the southwest and the Stanley mines to the northeast. Uranium minerals, primarily sooty pitchblende, torbernite, and autunite, are not confined to either vein system, but from the known data appear to occur in greater quantity in the steep vein system.

Dumont-Fall River region, by F. B. Moore and C. C. Hawley

In the Dumont-Fall River region about 8 1/2 square miles of surface have been mapped in detail and 31,000 feet of underground workings in 35 mines and adits have been mapped and examined for radioactivity. Eleven mines in the region, all of which contain veins of the composite type are known to show abnormal radioactivity.

Wall rock alteration investigation, by E. W. Tooker

The current investigation of wall rock alteration is designed to complement studies of the petrology, structure, and vein mineralogy of various districts of the Colorado Front Range with particular reference to (1) pitchblende mineralization and other mineral zonations; (2) types of host rock in the area; (3) types of vein structures, and (4) ore shoot locations and their use as a guide to ore. Field investigations began August 19, 1953, with reconnaissance examinations, including sampling that was done mostly in areas that had been completely mapped, where spectrographic and chemical data were available, and where post-mining alteration was at a minimum. The investigations to date substantiate in general the conclusions of Lovering and Goddard (USGS Prof. Paper 223, 1950), and the usually accepted pattern of alteration zones, from a silicified zone through sericitic and argillic zones into fresh rock, can be grossly seen along most veins. The thickness of zones appears to be related to the size of the vein and ore shoots in all host rock types. It is believed, however, that argillic alteration is much more widespread and important, than was previously reported.

The next six months will be devoted principally to map and report compilation and to laboratory studies of the ores, country rocks, and alteration products. Study of clay minerals will be included and is expected to provide much information because of the sensitivity of these minerals to environment. All mines exposing uranium-bearing veins will be checked and mapped in detail.

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

Pitchblende has been found at eight localities in the Ralston Buttes quadrangle, Jefferson County, Colo. (Adams, Gude, and Beroni, TEM-154), where it occurs with base-metal sulfides in shear zones that cut pre-Cambrian and igneous rocks. In addition, at least three occurrences of secondary uranium minerals are known in the quadrangle, and carnotite occurs at the old Leyden coal mine, less than 4 miles distant (Gott, TEM-132).

The current program includes (1) mapping of the quadrangle on a scale of 1:20,000 for publication at 1:24,000; (2) mapping of areas of significant mineralization and complex geology on a scale of 1:6,000; (3) large-scale mapping of pitchblende deposits; (4) systematic search for additional deposits of uranium; and (5) fundamental studies of the petrology and mineralogy of the country rocks and ores.

Geologic reconnaissance indicates that three of the major northwestward-trending faults shown by Lovering and Goddard (USGS Prof. Paper 223) in the area to the northwest continue southeast across the Ralston Buttes quadrangle. In order from north to south these faults are the Rogers "dike," the Hurricane Hill "dike," and the Junction Ranch "dike" (fig. 19). The common topographic expression of the faults in the quadrangle is negative relief, in contrast to the dike-like outcrop pattern to the northwest. The pitchblende occurrences in the Ralston Creek area (TEM-154) are along shear zones associated with the major Rogers fault; those in the Golden Gate Canyon area (TEM-154) are along shears associated with the southeastern extension of the Hurricane Hill fault (fig. 19). No pitchblende has as yet been reported from the vicinity of the Junction Ranch fault in the Ralston Buttes quadrangle.

The Guy Gulch area (fig. 19) in the southwestern part of the quadrangle was chosen for the initial mapping because the Junction Ranch fault crosses it and because the exposures permit a preliminary establishment of mapping units. About 8 square miles were mapped. The pre-Cambrian rocks have been subdivided into five preliminary units based largely on mineralogy, and several dark dike-like rocks of undetermined age and a syenite (?) dike of probable Tertiary age have also been mapped. The apparent horizontal offset of the major pre-Cambrian units along the Junction Ranch fault is about 4,000 feet, the north side being moved northwest relative to the south side. North of the fault a major overturned anticline is strongly suggested by the dips and the repetition of the units. Preliminary work suggests that the axial plane of the anticline dips north and the fold plunges west. However, the north limb of this structure on the south side of the fault is exceedingly complex and further work will be necessary to distinguish between large drag folds and major cross-warps.

In the Guy Gulch area approximately 11,000 feet of the Junction Ranch and associated faults were traversed with a scintillation detector, and samples from 10 prospect pits were examined with a geiger counter.

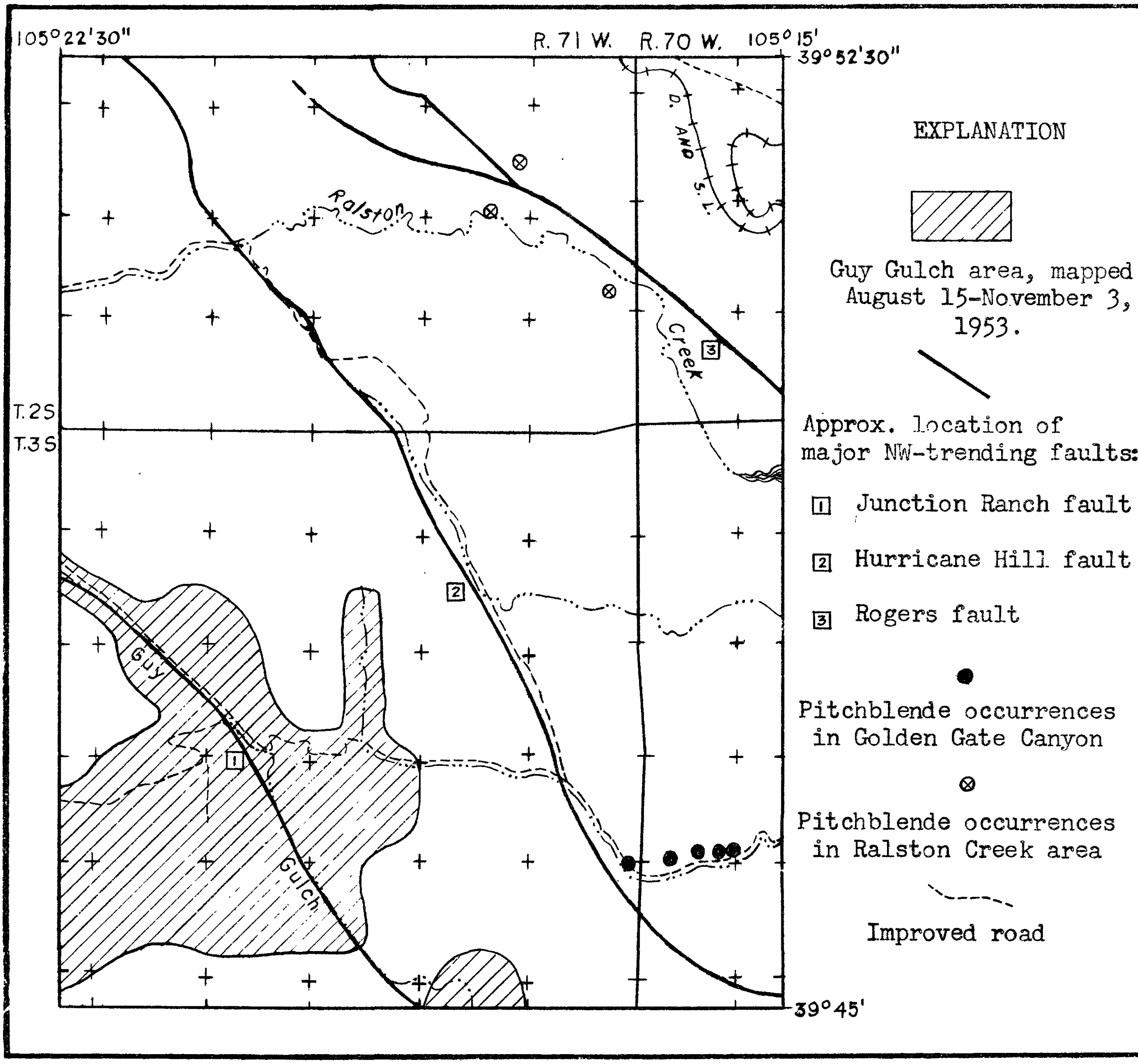
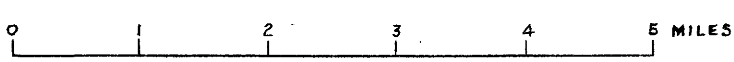


FIGURE 19.--INDEX MAP OF THE RALSTON BUTTES QUADRANGLE, JEFFERSON COUNTY, COLORADO



Although numerous abnormally radioactive areas were found, no significant anomalies (more than 0.05 MR/hr) were observed. Several areas along the Junction Ranch fault gave readings of 2 to 3 times background, probably because of the presence of large pegmatite dikes, but no significant deposits were found. However, as some of the known uraniferous areas in Golden Gate Canyon and along Ralston Creek gave similar readings, it cannot be stated at this time that the Junction Ranch fault system is barren of pitchblende deposits.

Reconnaissance of about 2 square miles in the vicinity of the Ralston Creek area indicates that the geology there is exceedingly complex. The area of the Schwartz mine, where 10 days were spent in connection with a DMEA exploration program, is especially difficult to interpret because much of the critical area is under heavy overburden.

San Juan Mountains, Colorado

Reconnaissance, by C. T. Pierson

Reconnaissance for radioactive minerals in the San Juan Mountains, Colo. was completed; the work was done in the western part of the mountains in 1951-52 and in the eastern and central parts in 1953.

During the 1953 field season search for radioactive minerals was made in 18 mining districts, including detailed coverage in the Summitville and Bonanza districts and spot checks in the Creede, Lake City, Carson Camp, Burrows Park, Whitecross, Eureka, Animas Forks, Spar City, Platoro, Axell, Jasper, Stunner, Embargo, Summer Coon, Beidell, and Sky City districts. Anomalous radioactivity was found in the Creede, Carson Camp, Burrows Park, and Bonanza districts, but a pitchblende (?) occurrence in the Bonanza district is the only one with possible commercial significance.

The Upper Uncompahgre, Silverton, Rico, and La Plata districts in the western San Juan Mountains were examined briefly in cooperation with T. Loomis of the AEC. No anomalous radioactivity was found in the Silverton district, but strongly radioactive samples from the Upper Uncompahgre and La Plata districts, and a weakly radioactive specimen from the Rico district were taken for laboratory studies.

A report on the results of the work in 1951 (TEI-310) was issued as USGS Circular 236, and a report on the 1952 program is in preparation. A report on the 1953 work as well as a general paper integrating the results of the 1951-1953 field and laboratory studies is scheduled to be completed by June 30, 1954.

Western San Juan Mountains, Colorado, by A. L. Bush

A preliminary resource study of the uranium-vanadium deposits of the Entrada sandstone in the western San Juan Mountains was completed during the 1952 field season; the results of this work were reported in TEM-298.

In June 1953, areal geologic mapping (scale 1:15,840) was begun, and detailed mine mapping (scale 1:480 and 1:600) was resumed to delineate the structural and stratigraphic setting of the uranium-vanadium deposits. Work to date has been largely in the Coventry 4 SE ($7\frac{1}{2}$ minute) quadrangle, with lesser amounts in the Dolores Peaks NE and Gray Head ($7\frac{1}{2}$ minute) quadrangles.

The sedimentary rocks range in age from the Permian Cutler formation through the Cretaceous Mancos shale. They are cut by numerous, closely spaced normal faults, with vertical displacements that range from a few inches to 300 feet or more. These faults appear to form a conjugate system (one set trends N. to N. 30° W., the other N. 60° W. to W.), superimposed on a series of broad, gentle, northwest-trending anticlines and synclines. The uranium-vanadium deposits are offset by both sets of faults. The faulting is related to the domal uplift of the San Juan volcanic pile and, more particularly, to the intrusion of stocks of diorite and diorite-monzonite. Sills of coarse porphyritic diorite have been intruded into the Cretaceous Dakota sandstone and Mancos shale.

The next 6-month period will be spent largely in map compilation, preparation of geologic sections, and petrographic and petrologic work on barren and mineralized Entrada sandstone and on the intrusive igneous rocks. Areal geologic mapping will be resumed in May 1954.

Boulder Batholith, Montana
by G. E. Becraft

Geologic mapping of the Jefferson City quadrangle, Mont., was completed during the reporting period; approximately 65 square miles was mapped, principally at a scale of 1:12,000, as part of the Survey's Trace Elements investigations of the Boulder batholith area of western Montana.

In the northwestern part of the quadrangle adjacent to the Clancy Creek area (TEI-257) and including the Rimini mining district, many radioactivity anomalies were detected. Most were very weak and with the exception of a few in the Rimini mining district were associated with chalcedonic vein zones. A secondary mineral, identified as metatorbernite, was identified at two of the locations--the Argonne gold mine and along a chalcedonic vein zone in SE¼ sec. 34, T. 9 N., R. 5 W. In the Rimini district weak radioactivity was detected on dumps along three base-metal-bearing structures. Although the uranium content is believed to be too low for production, several samples have been submitted for eU and U analyses.

In the southwestern part of the quadrangle adjacent to the Comet area (TEI-282), moderate radioactivity was detected on the dump of a caved shaft in sec. 4, T. 6 N., R. 4 W. Metatorbernite was found associated with limonitic material. This dump appears to be on a split of the Comet-Gray Eagle shear zone to the west.

All the mines and mine dumps in the Corbin-Wickes area near the center of the Jefferson City quadrangle were examined and no anomalous radioactivity was detected. Considerable lead, silver, zinc, and gold has been produced in this district from several mines along major shear zones similar to the Comet-Gray Eagle zone. With the exception of uranium in the Comet and Gray Eagle mines, the ore mineralogy appears to be the same; however, the Corbin-Wickes area is in a roof pendant of Cretaceous volcanics into which the Boulder batholith was intruded. It therefore is apparent that the roof pendant was an unfavorable host for uranium deposition. Additional mapping and radioactivity reconnaissance must be done to determine whether this is true only for the volcanics in the roof pendant or is also true elsewhere.

Uranium was found at the White Pine mine on the middle fork of Warm Springs Creek about 7 miles east of the eastern boundary of the Jefferson City quadrangle. This discovery extends the known uranium deposits several miles to the east. Selected samples are estimated to contain 0.5 percent eU. The uranium is apparently associated with base metals.

During the airborne magnetometer survey of the batholith, anomalous radioactivity was detected on two scintillation-type counters in SE$\frac{1}{4}$ sec. 29, T. 8 N., R. 7 W. This anomaly was not located in subsequent aerial reconnaissance in a light aircraft. Additional work is planned also for this area.

During the next six-months period, laboratory studies will be made on material collected and a bulletin on the Jefferson City quadrangle will be prepared.

Mineralogy and geochemistry
by George Phair

During July time was largely devoted to mineralogical studies of the pitchblende-coffinite ore from the Copper King Mine. As part of these studies, about a dozen photomicrographs of polished and thin sections have been made. It proved impossible to handpick a sample of the new tetragonal uranium mineral, coffinite, in purity adequate for chemical analyses. About one month of laboratory work remains before the results can be reported.

During late August the project was moved to Denver. As a result of the move research and report writing was curtailed in the interests of planning, purchasing, and setting up necessary laboratory equipment. Much time was spent in devising a suitable method for filing and making available data on "Uranium in Igneous Rocks and Veins" - data which for the most part will come from geologists outside the project.

A paper, "Notes on the differential leaching of uranium, radium and lead from pitchblende in H_2SO_4 solutions" by Phair and Levine was published in the August 1953 issue of "Economic Geology."

Once the facilities are in operation present plans call for a detailed investigation of the problems involved in sampling igneous rocks for uranium and radioactivity determinations in order to find out:

1. What are the precision and accuracy of the uranium and radioactivity measurements as applied to igneous rocks?

2. How well does the split taken into solution by the chemist represent the sample pulp?

3. How well does the sample pulp represent the outcrop?

4. How well does the outcrop represent the rock body?

The answers will necessarily be incomplete, but should make plain the major sampling pitfalls. As such they should be of interest not only to those immediately concerned with radioactivity studies, but also to those engaged in other studies of igneous rocks.

URANIUM IN CARBONACEOUS ROCKS

Reconnaissance

Coal in eastern states
by E. D. Patterson

A reconnaissance study of the radioactivity of coals in western Kentucky, northern West Virginia, and western Pennsylvania was made during the period. In western Kentucky a total of 59 samples from coal beds number 6, 7, 9, 11 and 13 was taken. None of the samples showed significant radioactivity; but canneloid shales overlying beds 9 and 11 showed as much as 0.005 to 0.009 percent eU. These shales cannot be considered promising sources of uranium under present conditions. No further work is planned in western Kentucky.

A total of 360 samples was collected from 86 mines in the counties of Mercer, Lawrence, Butler, Clarion, Allegheny, Westmoreland, Indiana, Cambria, Somerset, Jefferson, and Clearfield, western Pennsylvania. The beds sampled were the Brookville, Lower Clarion, Upper Clarion, Lower Kittanning, Middle Kittanning, Upper Kittanning, Lower Freeport, and Upper Freeport of the Allegheny series; the Bakerstown of the Conemaugh series; and the Pittsburgh and Redstone of the Monongahela series. None of the coals showed more than 0.002 percent eU. A thin layer of bone overlying the Upper Freeport bed in Clearfield County showed as much as 0.040 percent eU, but the coal above the bone layer showed no unusual radioactivity, nor did any of the other coals above, below, or on either side of the locality for a distance of two miles.

A total of 87 samples of coal and shale from 12 strip mines and four road cuts in north-central West Virginia was collected from the Pittsburgh and Redstone beds. None of the samples showed significant radioactivity.

A number of thin outcropping coals of the Dunkard formation of Permian age in northwestern West Virginia were checked with a scintillation detector, but no unusual radioactivity was found.

During the remainder of the fiscal year sampling and study of coals in Pennsylvania, West Virginia, Indiana, and Illinois will be continued.

Coal and lignite in western states

Utah-New Mexico, by H. D. Zeller

Utah.--Field work was conducted in three major areas in southern Utah: the Kaiparowits Plateau, the Henry Mountains, and Kolob Terrace. A total of 85 samples (57 coal, 9 carbonaceous shale, 12 volcanic rock, 3 sandstone, and 4 water) was taken.

A few 1 to 2-foot carbonaceous shale beds in the Dakota sandstone are estimated to contain 0.01 percent eU. These shale beds occur: (1) on the eastern edge of the Caineville dome (sec. 3, T. 29 S., R 8 E.), Wayne Co., Utah; (2) on the northwest flank of the East Kaibab monocline (sec. 6, T. 39 S., R. 1 E.), Kane Co., Utah; and (3) near Collet Creek along the northeast edge of the Kaiparowits Plateau (sec. 35, T. 37 S., R. 4 E.), Garfield Co., Utah.

A 6-foot coal bed in the Webster mine in Right-Hand Canyon near Cedar City, Iron Co., Utah, in the Straight Cliffs formation, was found to be slightly radioactive. The ash of coal from this and two other mines at the same horizon is estimated to contain 0.01 percent eU. The ash sample was taken from the waste dump of the Southern Utah Power Company's plant near Cedar City. Approximately 100 tons of coal from the three mines, averaging about 9 percent ash, are used a day.

A 2-foot bed of semi-anthracite next to an andesite intrusion near New Harmony, Utah, is estimated to contain 0.005 percent eU.

Other localities of carbonaceous rocks which may contain as much as 0.005 percent eU include: (1) a 3-foot coal bed in the Straight Cliffs formation in Middle Warm Creek at the southern end of the Kaiparowits Plateau; (2) an 8-inch coal in the Ferron sandstone near Factory Butte, Wayne Co., Utah; and (3) a 3-inch coal in the Straight Cliffs formation in Coal Canyon near Cedar City, Utah.

A volcanic flow rock near Antimony, Utah, on the west slope of the Aquarius Plateau contains an estimated 0.005 percent eU. A rhyolitic lava sheet at the top of the Brian Head formation just north of Cedar Breaks National Monument appears to be radioactive, but contamination from "fall out" at the time of the examination was considerable and no satisfactory estimates of radioactivity could be made.

New Mexico.--A lenticular carbonaceous shale in the Mesaverde formation near Chama, New Mexico, contains an estimated 0.004 percent eU. It is under an old erosion surface thought to have been covered by volcanic debris. Other coals lower in the stratigraphic section in this area show no radioactivity.

Southwestern Colorado and New Mexico, by E. H. Baltz, Jr.

Carbonaceous sediments of the Colorado Plateau of southwestern Colorado were examined during the 1953 field season. The areas examined are shown on the accompanying index map (fig. 20).

The only significant radioactivity noted in carbonaceous rocks is in bituminous shale, siltstone, and sandstone of the Paradox formation at the Bald Eagle prospect, sec. 24, T. 44 N., R. 17 W., San Miguel County, Colorado. A sample of the black shale contains an estimated 0.2 percent eU. Other outcrops of Paradox black shale in the adjacent area may contain 0.005 percent eU.

Traces of radioactive material were found in coal beds of the Upper Cretaceous Mesaverde group and the Fruitland formation on the northern rim of the San Juan Basin in Archuleta, La Plata, and Montezuma Counties, Colorado, and in the Barker dome area, San Juan County, New Mexico. At none of the localities examined did there appear to be more than an estimated 0.005 percent eU. Carbonaceous sediments and volcanic rocks of the Upper Cretaceous-Paleocene Animas formation and the Paleocene-Eocene Wasatch formation were examined in the northern San Juan Basin. The only radioactivity found was an estimated 0.004 percent eU in an acidic tuff near the base of the Wasatch formation in sec. 19, T. 34 N., R. 10 W., La Plata County, Colorado.

Two small basaltic plugs in the canyon of Mancos River (sec. 24, T. 35 N., R. 14 W., and sec. 15, T. 33 N., R. 15 W.) southwest of Mancos, Montezuma County contain an estimated 0.005 percent eU. Examination of the plugs did not disclose any mineralization of stoped material or wall rock of Mancos shale and Mesaverde sediments.

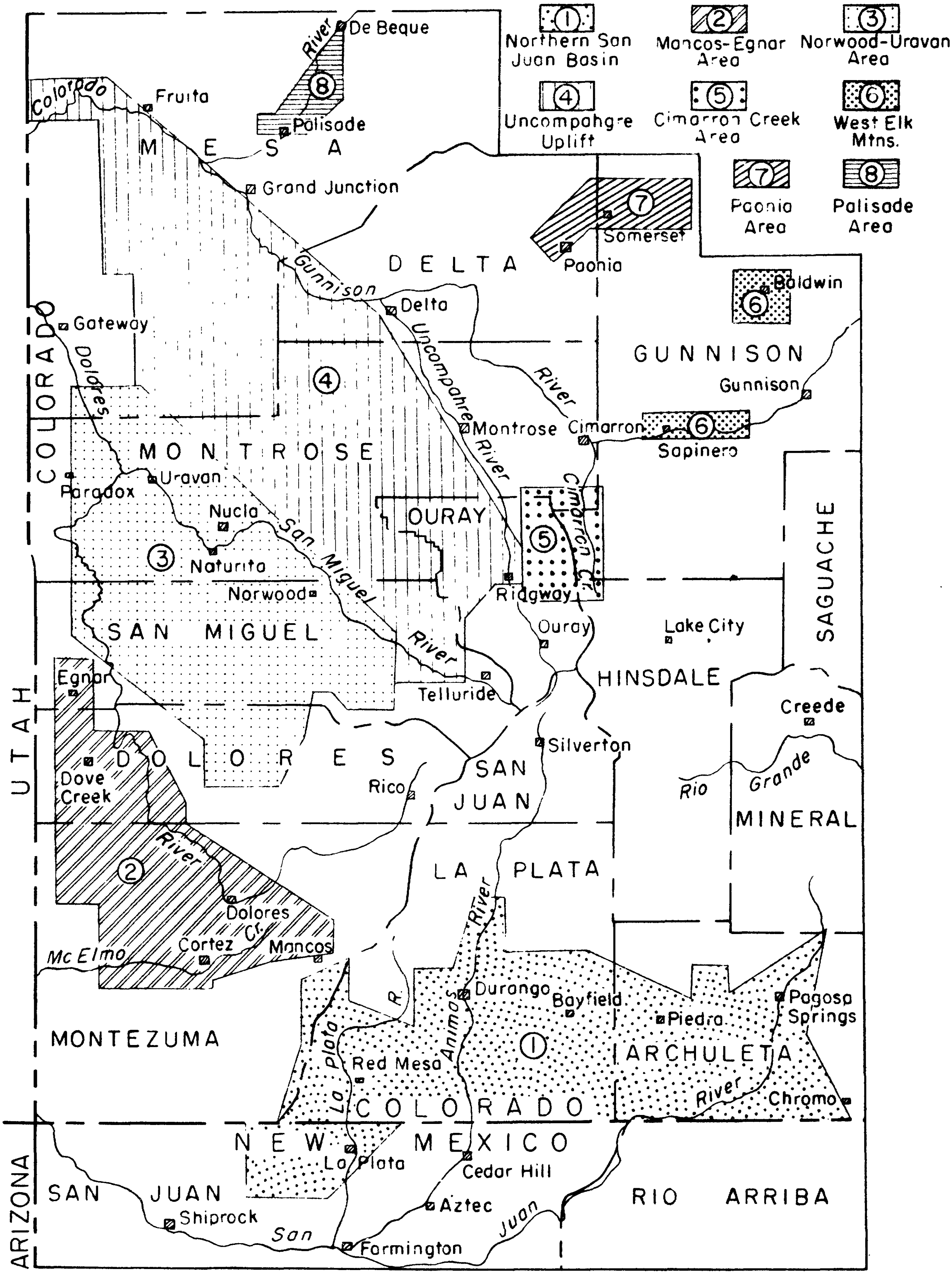


FIGURE 20--INDEX MAP OF SOUTHWESTERN COLORADO AND NORTHWESTERN

Slight traces of radioactive material were found in coal and carbonaceous shale of the Dakota formation in the Mancos-Egnar area; in the Norwood-Uravan area; and on the Uncompahgre uplift. At none of the localities examined did the Dakota sediments appear to contain more than an estimated 0.006 percent eU.

Tertiary volcanics of the San Juan tuff and underlying coal of the Mesaverde formation were examined in the drainage of Cimarron Creek, northwestern San Juan Mountains, but no radioactivity was detected.

No significant radioactivity was found at outcrops of the Dakota formation and coal of the Mesaverde formation on the south and east sides of the West Elk Mountains, Gunnison County, and in the vicinity of Paonia, Gunnison and Delta Counties, and near Palisade, Mesa County.

The Dakota sandstone and Purgatoire formation on the Canadian Escarpment in Harding and San Miguel Counties, northeastern New Mexico, were examined. Traces of radioactivity were noted in carbonaceous shale of both formations. A prospect of the Hunt Oil Company in sec. 30, T. 17 N., R. 24 E., San Miguel County, may contain as much as 0.2 - 0.5 percent eU. Mineralization is in the middle sandstone member of the Chinle formation of Triassic age which crops out continuously along the Canadian Escarpment between Pecos River and Ute Creek in San Miguel and Harding Counties.

Western lignites

<u>Ekalaka Lignite Field, Carter County, Montana,</u> by J. R. Gill

During the 1953 field season approximately six weeks were spent in geologic investigations in the Ekalaka lignite field, Carter Co., Montana. An area of about 70 square miles was mapped on aerial photographs at a scale of 1:20,000. Radioactive carbonaceous shales and lignites occur in the Ludlow formation (Paleocene) and have a possible areal extent of about 20 square miles. Much of the lignite-bearing outcrop of the Ludlow formation is obscured by slope wash and landslide debris from the overlying Tongue River (Paleocene) and Arikaree (Miocene) formation. This factor combined with the lenticular nature of the lignite makes evaluation of reserves difficult on the basis of present information.

On the weathered outcrop, radioactive lignite as much as 8 feet thick contains 33.8 percent ash and 0.014 percent uranium in the ash. Thicker beds of lignite have been found and contain comparable amounts of uranium. Most of the lignite contains an abundance of analcite and other zeolites in addition to barite, satinspar gypsum and calcium carbonate travertine. There are no known exposures of fresh lignite in the area and it is impossible to ascertain whether these recognizable impurities are a surficial feature of weathering or are present in the fresh lignite behind the outcrop. As these impurities contribute to the high ash content they would adversely affect the use of the lignite as a potential source of fuel from which uranium might be a significant by-product.

Radioactive ironstone concretions interbedded in thin- to massive-bedded coarse-grained sandstones are present in the Tongue River formation in the Ekalaka Hills area. These sandstones are lithologically similar to the massive, coarse-grained uranium-bearing sandstones of the Wasatch formation in the Pumpkin Buttes area of the Powder River Basin (Circular 176).

North Dakota, by G. W. Moore

In the HT Butte and Chalky Buttes area, Slope County, North Dakota, uranium occurs in two lignite beds in the Sentinel Butte member of the Fort Union formation of Paleocene age: the Slide Butte bed and the Chalky Butte bed (see fig. 21). These two lignites underlie an area of about 9 square miles. The lower bed, the Slide Butte, is the first lignite below the Oligocene unconformity in the southern part of the area but in the northern part of the area where a greater thickness of Paleocene rocks has been preserved, the stratigraphically higher chalky Buttes bed is present. Where the Chalky Buttes bed is present the radioactivity of the Slide Butte bed is greatly reduced. The relationship of the uranium-bearing lignite beds to the overlying Oligocene rocks suggests that the uranium has been introduced by downwardly moving ground-water. Rocks of the White River group are a recognized source of uranium in other areas (TEI-238).

On Bullion Butte, in Billings and Golden Valley Counties, North Dakota, uranium is also present in the highest lignite bed in the Sentinel Butte member of the Fort Union formation which is also unconformably overlain by rocks of the White River group. About 1 1/2 square miles are underlain by this bed which ranges in thickness from 0.6 to 12.0 feet. The stratigraphically lower beds are also mineralized but contain smaller quantities of uranium.

In the Sentinel Butte area, Golden Valley County, North Dakota, a uraniferous lignite bed is in the Sentinel Butte member about 20 feet below the Oligocene unconformity. This bed ranges in thickness from 0 to 7.0 feet and underlies about 1/2 square mile. Where the upper bed is absent, stratigraphically lower beds are also mineralized.

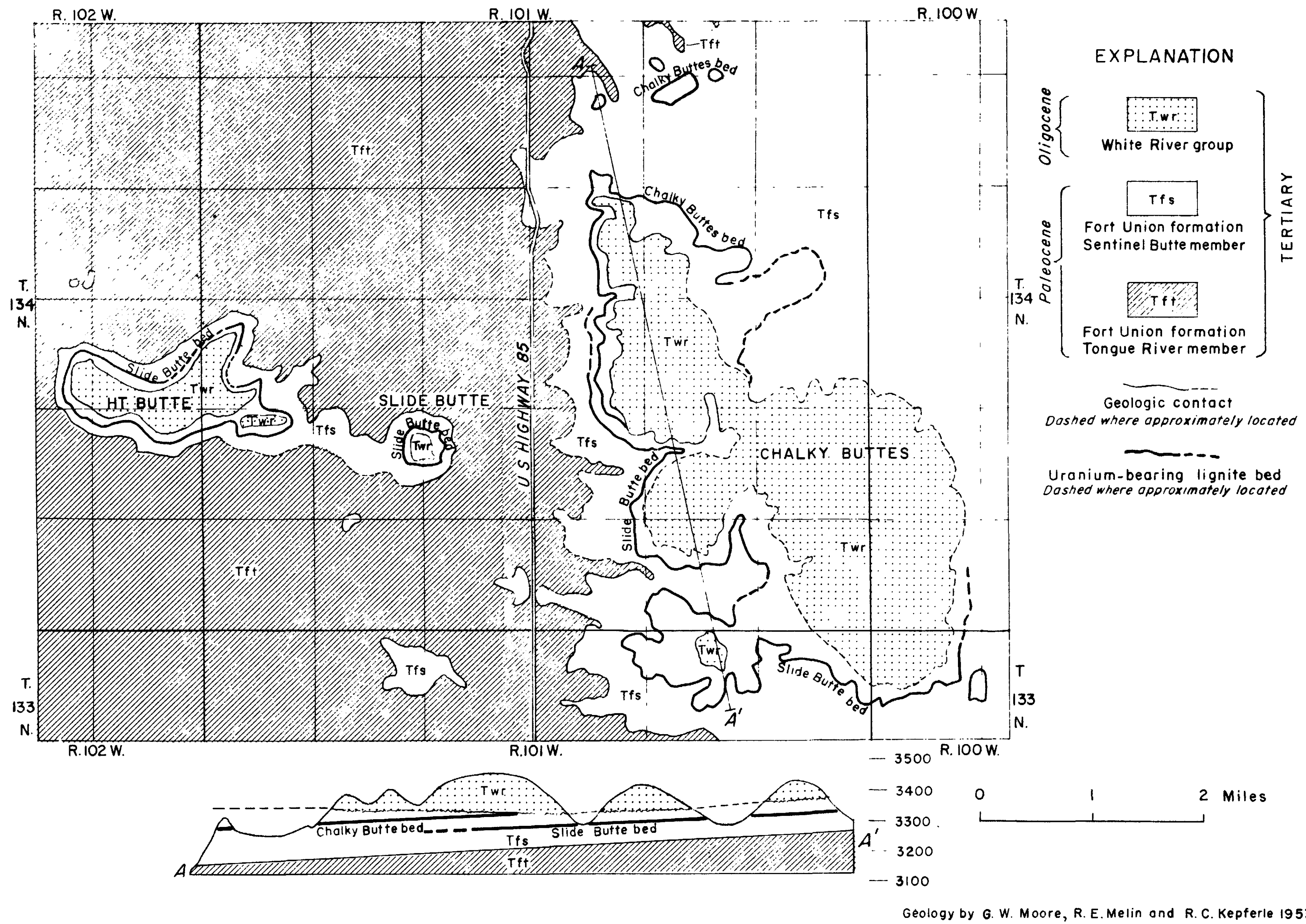


FIGURE 21--GEOLOGIC MAP AND SECTION OF HT BUTTE AND CHALKY BUTTES, SLOPE COUNTY, NORTH DAKOTA

Four bulldozer cuts were made in the Bullion Butte area and one cut in the Sentinel Butte area to expose radioactive lignite beds where no natural exposures occur.

Black shale in eastern states
by J. F. Pepper

Review of literature was begun, to collect and study all available information on the distribution, thickness, and geologic setting of each black shale in the East. Preliminary survey shows that there are approximately 75 named black or partly black shales east of the Mississippi River besides a large number of unnamed black shales that are referred to in geologic sections in some areas.

Investigation during the reporting period was largely concerned with some of the Devonian black shales of New York State, particularly the Dunkirk in western and west-central New York. Radioactivity measurements were made at 28 localities. Results of previous field mapping and of the radioactivity measurements of the Dunkirk were compiled. The Dunkirk shale contains .003 - .004 percent eU based on field readings. The radioactivity appears to decrease from west to east, perhaps related to an increase in silt content of the shale. The report shows in a qualitative way the relationship of the eU content to thickness of the shale, and compares briefly the Dunkirk and its eU content to the Chattanooga shale, to which it is approximately related in age.

Black shales in the Midcontinent
by D. H. Eargle

Analytical data on the radioactivity of Midcontinent black shales were assembled and synthesized from Trace Elements reports and unpublished records. Some of the well data were supplied by oil companies and the AEC. Copies of cards showing analyses of Midcontinent black shales and radioactive material were duplicated. Information on the presence of radiolarians in cherts and siliceous shales and a bibliography on this subject were assembled.

A descriptive log of a well in the Atoka formation in Franklin County, Arkansas, was prepared. The shales in this well have abnormally high radioactivity as revealed by gamma-ray logs. Two subsurface samples from the radioactive zone were submitted to the Trace Elements laboratory.

During the next 6 months the project will continue to assemble and synthesize information on the radioactivity and lithology of Midcontinent black shales and concentrate on several of the formations or groups of rocks in the Coastal Plain that are known to be somewhat radioactive, such as the Del Rio clay, Eagle Ford shale, and Tertiary shales. Later, work will be begun on the Paleozoic rocks. Detailed stratigraphic sections will be made to relate radioactivity to lithology and stratigraphic position. Radioactivity of these formations will be measured by instrument traverses on surface exposures and by study of the gamma-ray logs from the subsurface.

The regional variations in the radioactivity of these formations will be analyzed and an attempt to relate the radioactivity to the position in the basins in which the sediments were deposited will be made.

Black shales in Montana, Idaho, and northern Utah
by W. J. Mapel

Outcrops of black shales were checked for radioactivity and sampled in central and western Montana, northern Utah, and Idaho. Particular attention was given to formations that appeared from previous work to have possibilities of containing 0.005 percent or more uranium. Gamma-ray logs of 140 wells in Montana have also been checked for radioactivity anomalies; this study is continuing.

A bed of black shale at the base of the Madison limestone (early Mississippian) gives radioactivity readings of twice background at several places in southwestern Montana. The shale ranges in thickness from 1 to 5 feet where sampled. A black shale unit at about the same stratigraphic position in the subsurface in the Williston Basin of North Dakota, Montana, and Canada, which ranges in thickness from a few inches to more than 100 feet, locally registers anomalies more than five times background. Surface and well data are being assembled to evaluate the potentialities of this unit.

The Heath shale, which is known to contain 0.007 percent U near Forestgrove, Montana, was rechecked and also sampled at several other places in Montana. The uranium content of the shale, however, appears low at most places visited.

No black shale formations in the region, other than those described above, appear to be more than mildly radioactive.

During the reporting period 159 samples were taken from 90 localities, representing 24 formations ranging in age from pre-Cambrian to Permian. The distribution by states follows:

State	No. localities	No. samples
Montana	65	115
Utah	7	21
Idaho	18	23
TOTAL	90	159

Four occurrences of unusual radioactivity in rocks other than black shales were noted. A 10-foot bed of carbonaceous shale in the Sappington sandstone member of the Threeforks formation (Devonian) near Trident, Gallatin Co., Mont., is 2 to 3 times more radioactive than background; a skarn in the Madison (?) limestone near Maxville, Granite Co., Mont., is about 4 times more radioactive than background; a magnetite-bearing bed as much as 7 feet thick at the top of the Virgelle sandstone near Choteau, Teton Co., Mont., is about 4 to 5 times background; and a small deposit of tufa near Home, Baker Co., Ore., is about 10 times more radioactive than background.

Black shale in Colorado, New Mexico, and eastern Utah
by D. C. Duncan

Black shale deposits principally of Mesozoic and upper Paleozoic age were examined and tested for radioactivity with a carborne recording scintillation detector at numerous localities in Colorado, New Mexico, and eastern Utah. The reconnaissance was directed mainly toward examination of black shales of Pennsylvanian age that were known to contain a few thousandths percent to as much as 0.02 percent uranium at a few widely separated localities in Colorado. No extensive black shale zones of minable thickness and significant radioactivity were found. A carbonaceous shale about 4 feet thick and presumably of small extent in the Maroon Formation of Pennsylvanian age was found to be radioactive in the vicinity of Vale Pass, Eagle County, Colorado. According to field estimates the shale averaged about 0.01 percent eU.

Black shales in Nebraska and South Dakota
by H. A. Tourtelot

The Sharon Springs member at the base of the Pierre shale is radioactive where exposed in northern Nebraska and in South Dakota and gamma-ray logs of wells drilled for oil and gas in South Dakota, western Nebraska, and Kansas show that the formation is conspicuously radioactive in the sub-surface. The shale is about 70 feet thick in northern Nebraska and ranges in thickness from 7 to about 35 feet in exposures along the Missouri River but may be as much as 100 feet thick on the east side of the Black Hills. A channel sample of the basal 1 1/2 feet of the shale along the Missouri River contains 0.010 percent uranium; a grab sample of the upper part of the sequence on the east side of the Black Hills contains 0.002 percent uranium.

The White River formation of Oligocene age rests unconformably on chalky shale in the Niobrara formation around the Chadron anticline in northern Nebraska and along the east side of the Black Hills. The chalky bluish-gray shales are altered to bright-yellow to orange ferruginous shale as much as 30 feet thick beneath the cover of the White River formation. The gray shale just below or within the lower part of the altered shale, is radioactive. A grab sample from exposures about 8 miles west of Pine Ridge, South Dakota, contains 0.10 percent equivalent uranium and 0.015 percent uranium. Gray chalky shale in the Niobrara formation is not radioactive where it is not overlain by an altered zone apparently related to the overlying White River formation.

Asphaltite and petroleum
by N. W. Bass

A total of 115 one-gallon samples of crude oil from fields distributed through parts of nine states were collected and sent to the Trace Elements laboratory at Denver for analysis for trace elements. The fields to be sampled were selected so as to include fields with heavy crude oils, fields that contain a high percentage of sulfur, and other fields whose oils contain a high percentage of nitrogen. In Oklahoma and Kansas, fields were selected for wide differences in composition of of crude oils. No analyses for trace elements have yet been received.

Distribution of the samples taken to date is given below:

State	No. of oil fields sampled	No. samples crude oil	No. samples oil field brine
Wyoming	22	42	14
Oklahoma	12	18	8
Kansas	11	18	8
Colorado	5	10	2
Arkansas	4	7	2
Utah	4	6	2
Montana	5	8	0
New Mexico	2	4	1
Texas	1	2	0
Total	66	115	37

The stratigraphic distribution of sands from which oil samples were obtained follows:

Age of oil sand sampled	No. of samples
Tertiary	10
Cretaceous	17
Jurassic	9
Triassic	5
Permian	11
Pennsylvanian	40
Mississippian	5
Ordovician	16
Cambrian	2
Total	115

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

Reconnaissance for uranium in asphaltic rocks involved examination and sampling of deposits in California, New Mexico, Oklahoma, Texas, and Utah. Most of the localities examined were those which have been worked or prospected as commercial asphalt deposits. All localities were checked with a Geiger counter, and none showed above-normal radioactivity. Final results of sampling await radiation and chemical analyses. The map, figure 22, shows the location of districts examined.

District studies

Coal and lignite investigations

Mendenhall area, Slim Buttes, Harding County, South Dakota, by J. R. Gill

Core drilling by the Bureau of Mines in the Mendenhall area was in progress from October 1952 to June 1953, during which time 42 holes totalling 9,684 feet were completed. Of the holes, 31 were successful in recovering a major portion of the mineralized lignite. A preliminary study of the analyses for 75 percent of the holes indicates that an area of more than 4,000 acres is underlain by radioactive lignite having a mineralized thickness in excess of 4 feet (fig. 23).

The Mendenhall area is underlain by three important lignite beds in the Ludlow formation of Paleocene age, from top to bottom the Mendenhall rider, the Mendenhall bed, and the Olesrud bed. These lignite beds dip gently to the north and are truncated by rocks of the overlying White River group of Oligocene age (fig. 24). With few exceptions, the stratigraphically highest lignite below the base of the White River group is the only

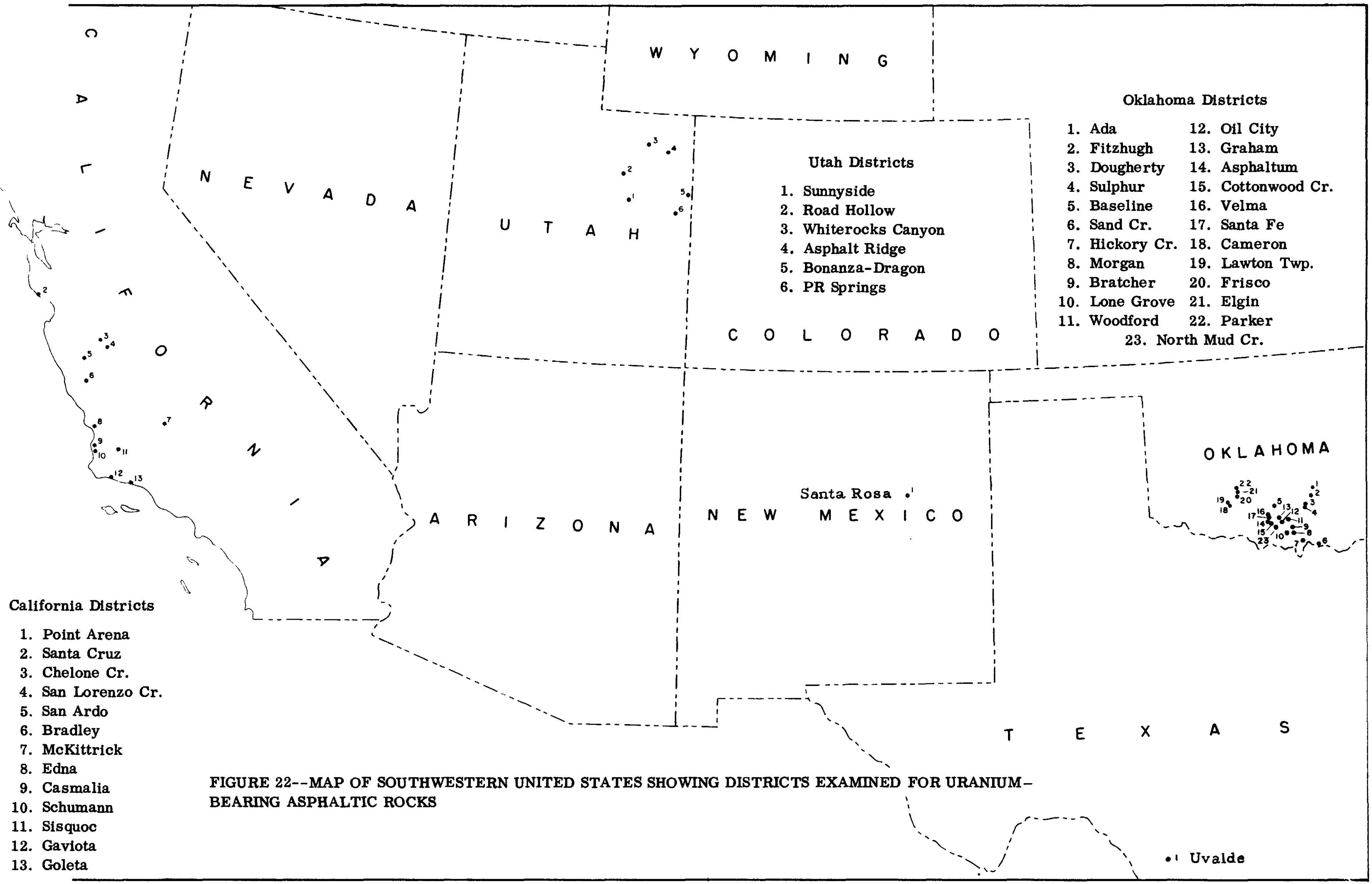


FIGURE 22--MAP OF SOUTHWESTERN UNITED STATES SHOWING DISTRICTS EXAMINED FOR URANIUM-BEARING ASPHALTIC ROCKS

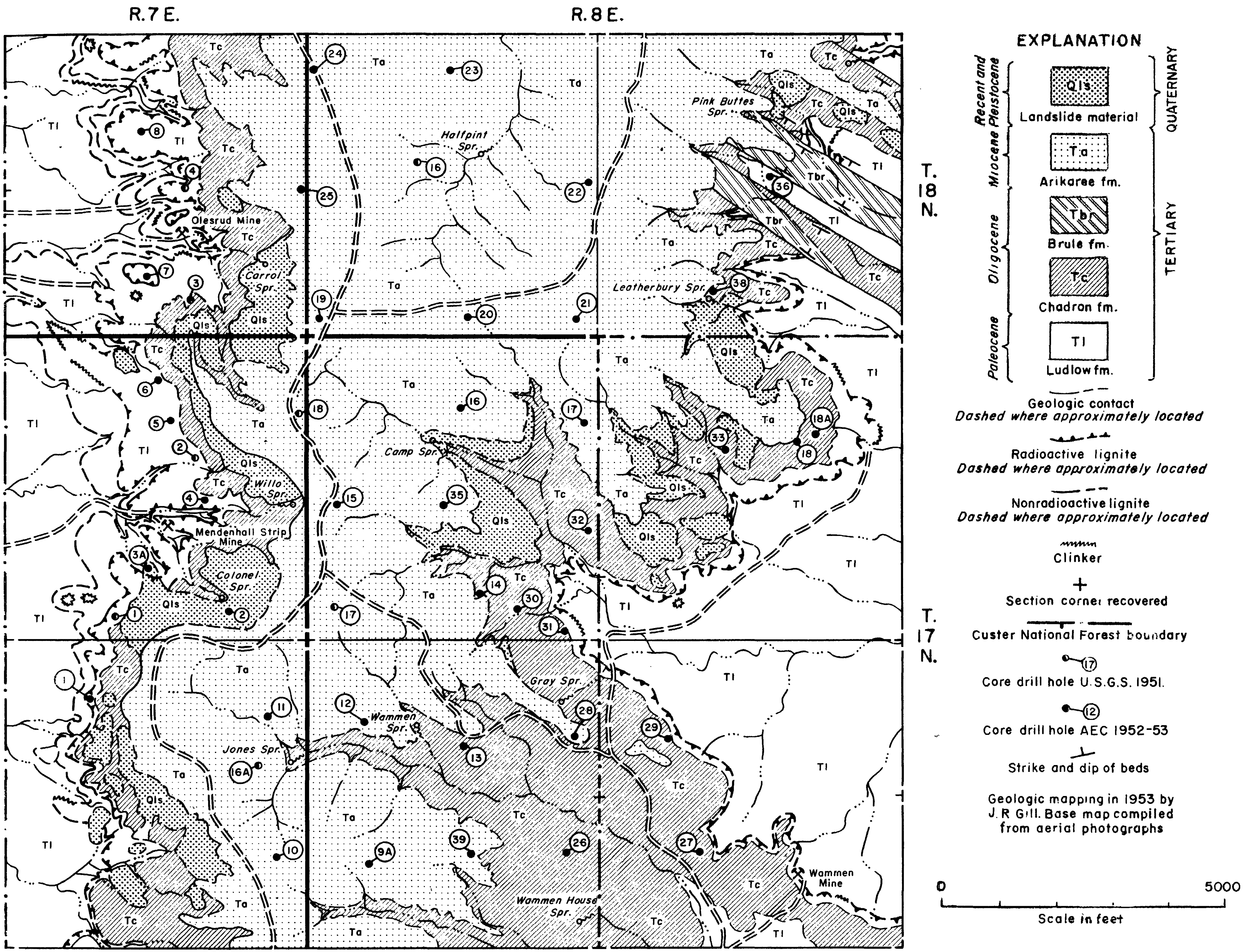


FIGURE 23--GEOLOGIC MAP OF THE MENDENHALL AREA, SLIM BUTTES, HARDING COUNTY, SOUTH DAKOTA, SHOWING LOCATIONS OF CORE DRILL HOLES

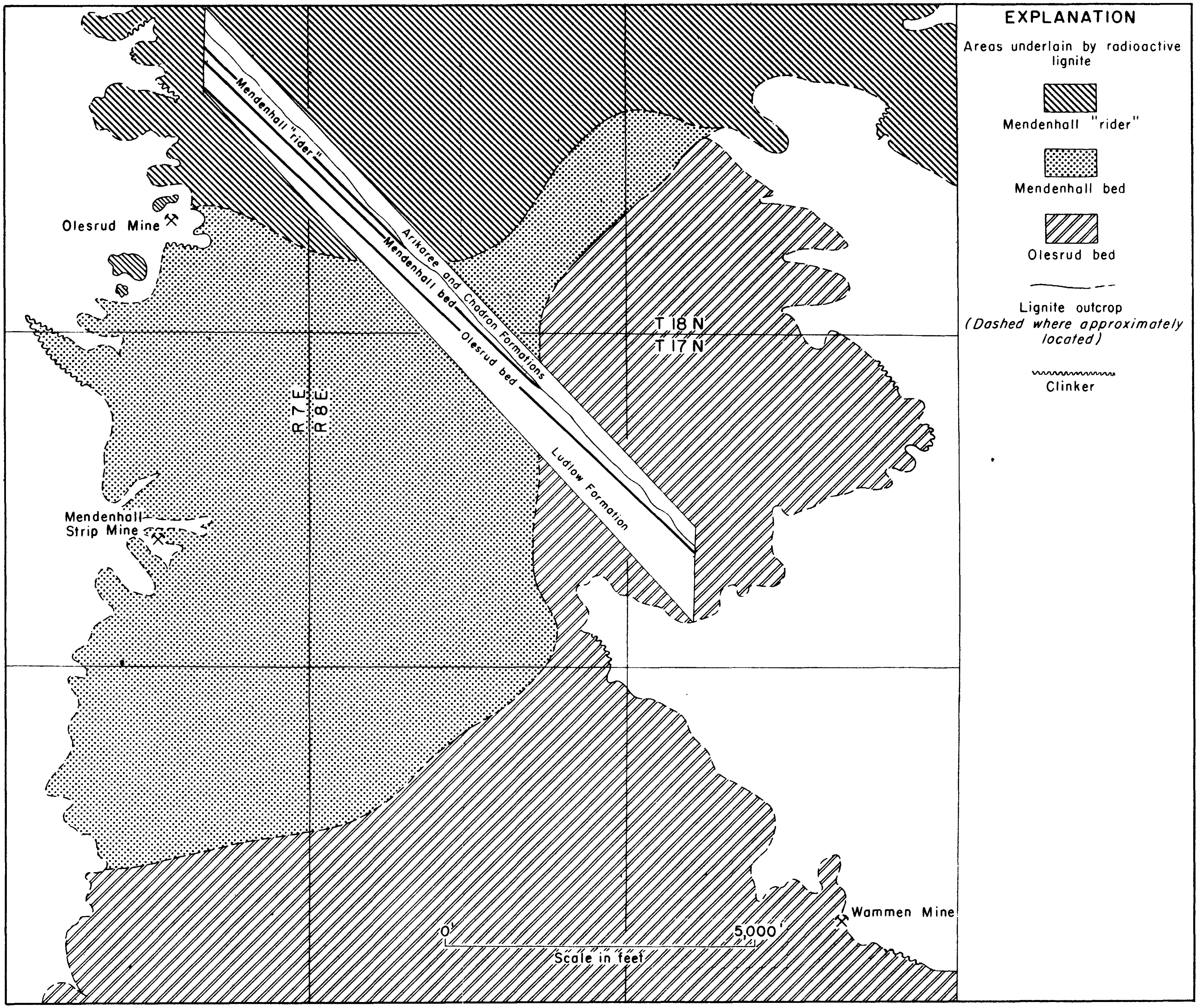


FIGURE 24.--SKETCH MAP SHOWING AREAL DISTRIBUTION OF RADIOACTIVE LIGNITES IN THE MENDENHALL AREA, SLIM BUTTES, HARDING COUNTY, SOUTH DAKOTA, 1953

lignite that is radioactive. In the northern part of the area, the Mendenhall rider is the highest bed; in the central part of the area the Mendenhall bed is the highest; and in the southern part the Olesrud bed is the highest. Although the Olesrud bed underlies all of the area, it is radioactive only where the Mendenhall rider and Mendenhall bed have been removed by erosion prior to the deposition of the overlying White River group. Similarly, the Mendenhall bed is radioactive only where the Mendenhall rider has been removed by erosion.

Correlation of lignite beds encountered in the drill holes and their relationship to the White River-Ludlow unconformity are shown in the accompanying fence diagram (fig. 25).

Goose Creek district, Cassia County, Idaho, by W. J. Mapel and W. J. Hail

Carbonaceous shale zones in the lower part of the Salt Lake formation were tested by 12 core holes drilled in the central part of the Goose Creek district during August and September 1953. The Barrett carbonaceous shale zone was penetrated in nine of the drill holes, and carbonaceous shale zone B, 160 feet below the Barrett zone, was penetrated in one hole. Three holes found no carbonaceous shale owing to erosion of the shale beneath local unconformities in the Salt Lake formation. Figure 26 shows the location of the drill holes, and figure 27 shows the thickness and radioactivity of carbonaceous beds found in drilling.

A 5-foot bed of carbonaceous shale at a depth of 243 feet in hole 2 was the most radioactive bed found. The upper part of this bed, which is in Zone B, may contain as much as 0.1 percent U. Where sampled at the surface about a mile to the south, zone B contains a maximum of 0.009 percent U. Carbonaceous beds found in drilling the Barrett zone may contain locally as much as 0.02 percent U.

Fig. 25—Fence Diagram Showing Correlation and Thickness of Lignite Beds Encountered in the AEC–USBM Drilling Program in the Mendenhall Area, Slim Buttes, Harding County, South Dakota, 1952–53.

(See page 284.)

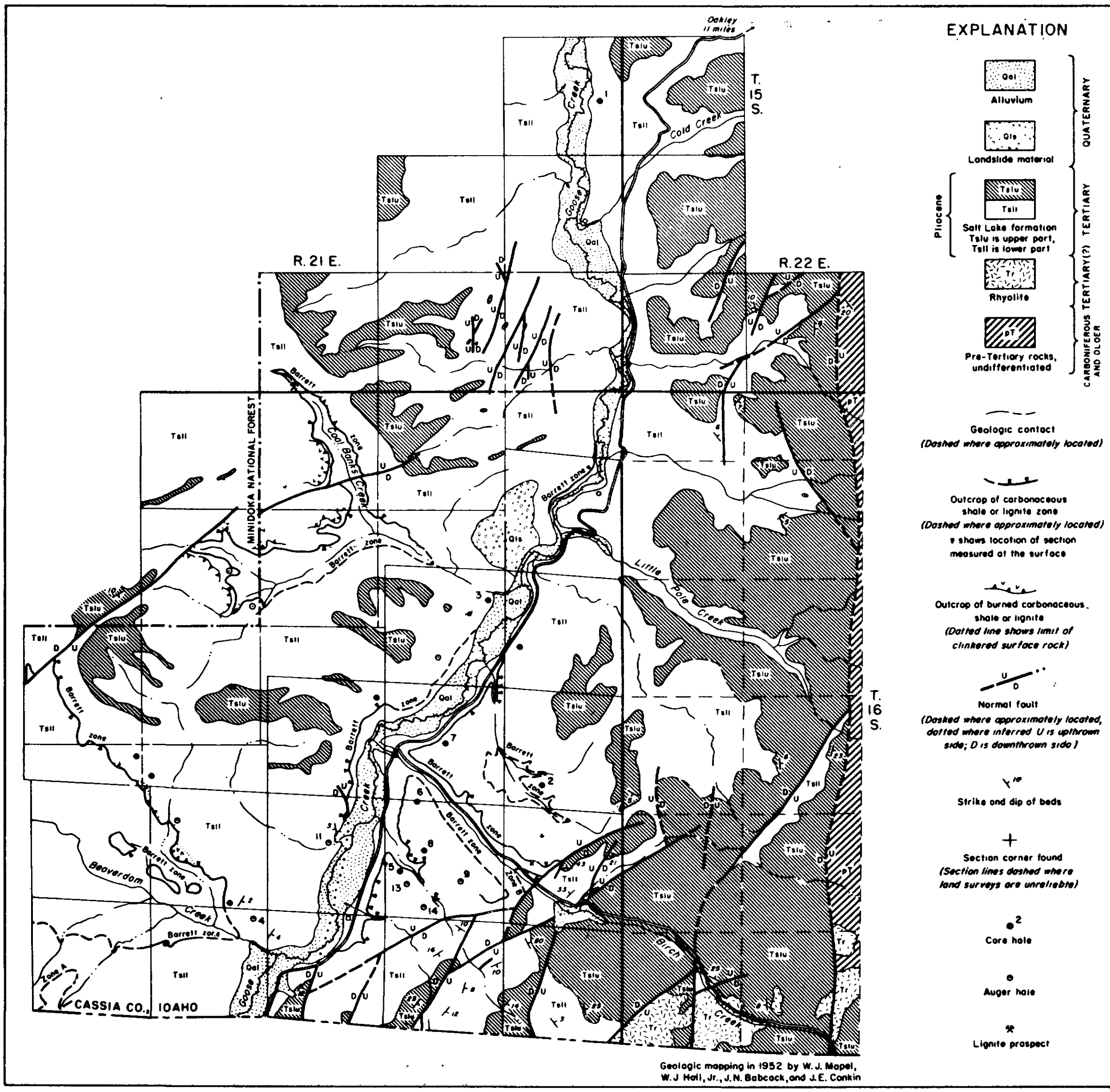


FIGURE 26.--GEOLOGIC MAP OF THE CENTRAL PART OF THE GOOSE CREEK DISTRICT SHOWING THE LOCATION OF CORE HOLES

0 1 2 miles
SCALE

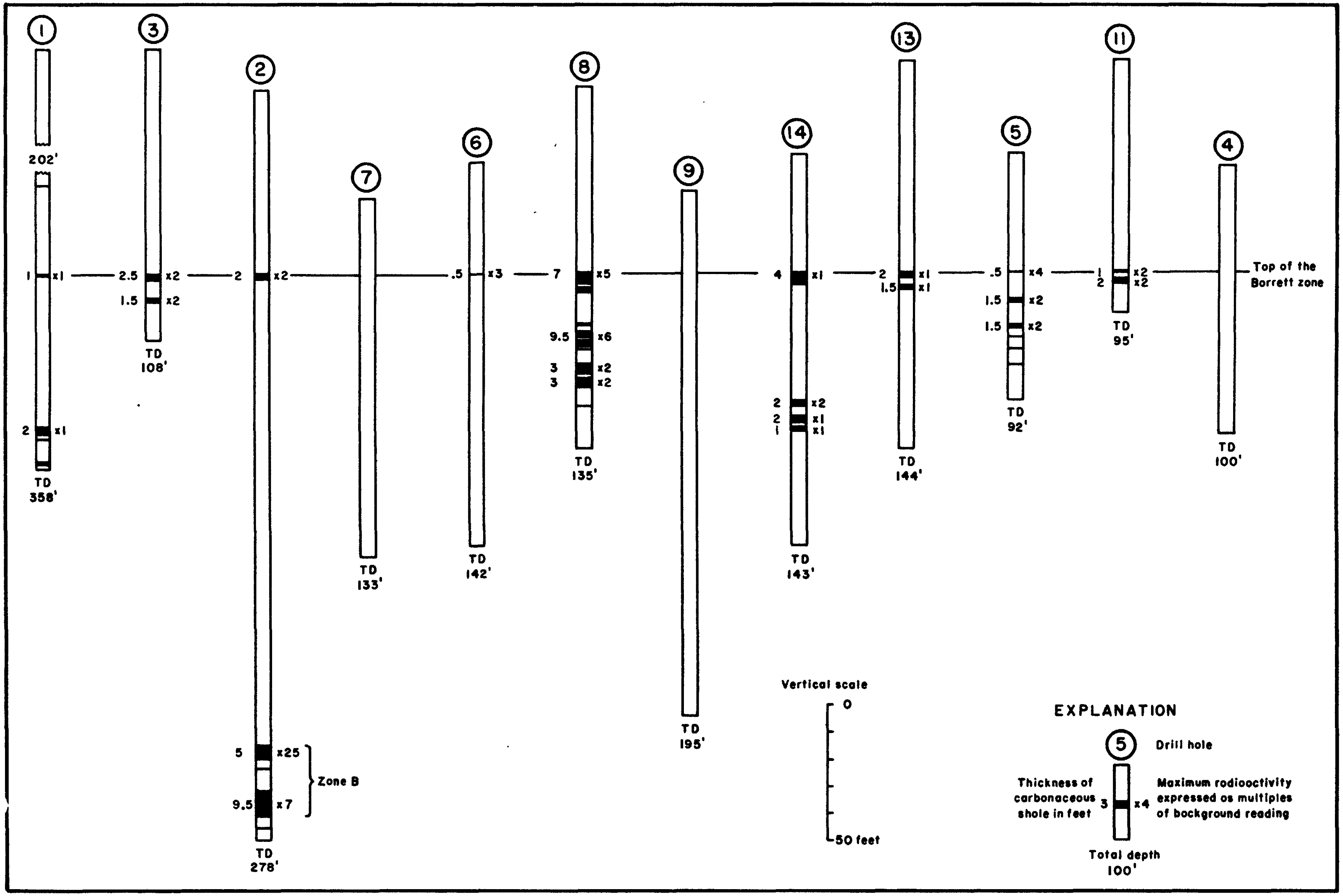


FIGURE 27.--DIAGRAM SHOWING THE THICKNESS AND RADIOACTIVITY OF CARBONACEOUS SHALE FOUND IN DRILL HOLES, GOOSE CREEK DISTRICT, IDAHO

Beds of carbonaceous shale in the Goose Creek district are known to contain about 0.1 percent U at 2 localities. The first, found previously by surface sampling, is in the Barrett zone in sec. 26, T. 16 S., R. 21 E. The second, found by drilling, is in zone B in sec. 24 of the same township. The highly uraniferous shale known to occur in the Barrett zone seems to be confined to a small pocket in sec. 26 near the outcrop of the bed. Data from hole 2 is inconclusive in showing the extent of uranium-rich shale in zone B.

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

Exploratory core drilling for uranium-bearing coal for the second season in the Red Desert area, Sweetwater Co., Wyo. (fig. 28) began on June 27, 1953, and concluded November 25, 1953. A total of 60 core holes totalling 12,677 feet, and one 8-inch core hole 106 feet deep were completed.

Statistical data are tabulated below:

Table 4.--Core drill and sample data on Red Desert area

	Total (feet)	Average per hole (feet)
NX drilling	12,676.9	209.6
NX casing	3,417.7	57.0
Coal penetrated	1,237.0	20.6
TE samples	2,330	
Bur. Mines fuel samples	94	
Bur. Mines oil shale samples	10	
Core to Coal Laboratory	936.5	
Eight-inch hole	106.0	

Coal core from 21 NX holes and the 8-inch hole was shipped to the Coal Geology Laboratory at Columbus, Ohio. Core from 16 holes was crushed and split into equal fractions for submittal to the Trace Elements Washington Laboratory for uranium analysis and to the Bureau of Mines' Pittsburgh

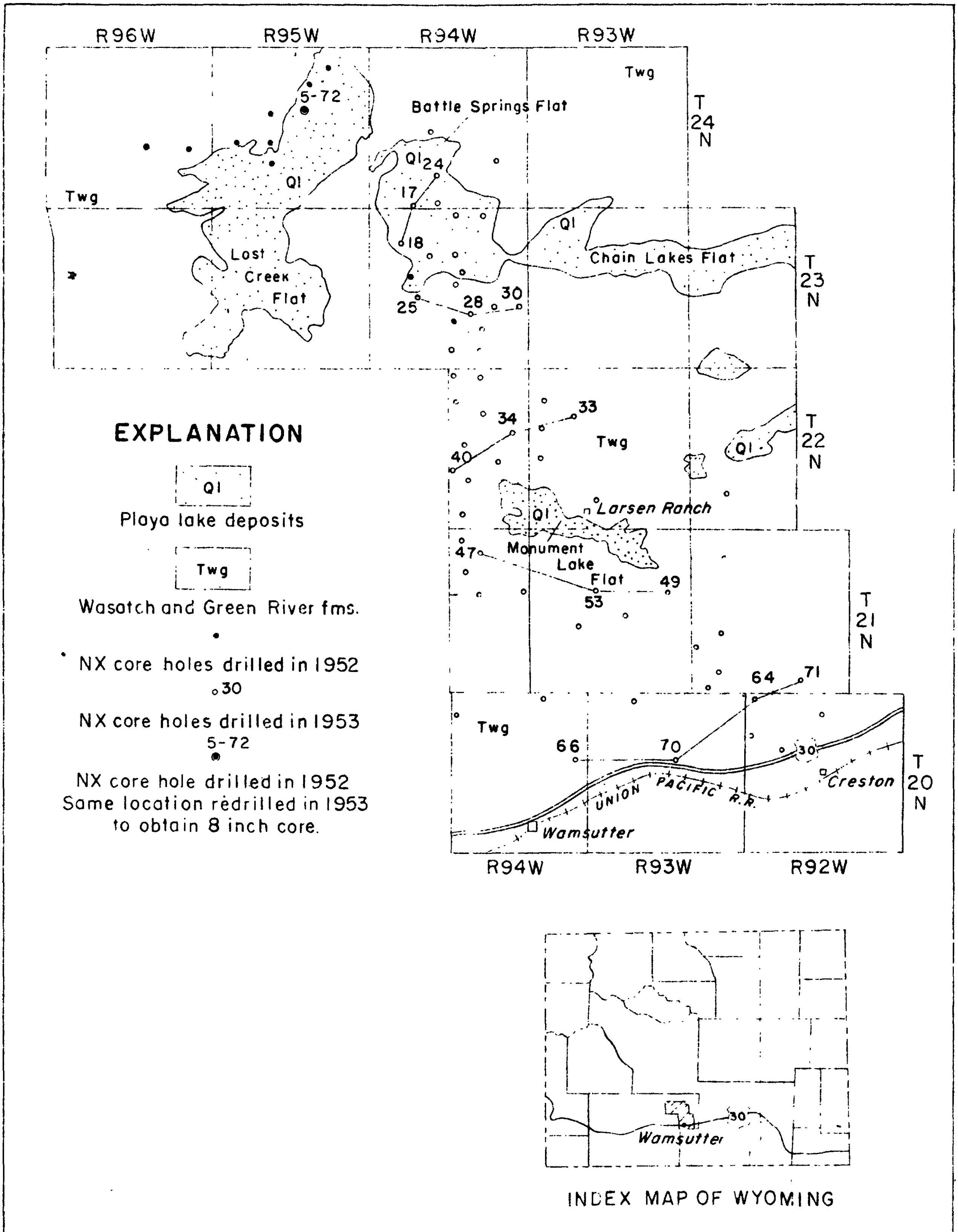


FIGURE 28.--SKETCH MAP SHOWING LOCATIONS OF CORE HOLES TESTING URANIUM-BEARING COAL, RED DESERT AREA, SWEETWATER COUNTY, WYOMING 1953

Laboratory for fuel analysis. Coal core from the remaining 23 holes was sampled for uranium analysis only. Shale samples were submitted to the Bureau of Mines Laramie Laboratory for shale oil analysis. A truck-mounted power auger completed 142 holes for a total footage of 5,653 feet. As few chemical analyses are now available uranium grade is estimated from radiometric determinations of coal core made by J. M. Schopf at the Geological Survey's Coal Geology Laboratory, Columbus, Ohio. The average uranium content of the coal determined from these readings is about 0.003 percent although locally coal as much as 6.5 feet thick contains 0.007 percent uranium and 0.05 percent uranium in the ash.

Data from the drilling reaffirms the pattern of relationship between uranium content of lithofacies distribution prepared earlier; i.e., uranium content rises to the east as the enclosing rocks become coarser-grained and more permeable. There is a complex interfingering of the lithotypes, the source of the sediments lying to the northeast. Coal beds are also high in uranium where in contact with topographically high cobble gravels of possible Miocene age. There appears also to be a close relationship between the cyclic distribution of lithotypes vertically and the uranium content of the coal. The typical cycle of deposition is sandstone, then coal, then clay shale. The coal in these cyclothems usually has a higher uranium content at the bottom of the bed adjacent to the permeable sandstone. The coal beds reach maximum thickness in the middle part of the area and thin rapidly to the northeast and to the southwest (fig. 29). They are little disturbed and dip from one to three degrees.

Western Red Desert area, Sweetwater County, Wyoming, by George N. Pipiringos

During the summer of 1953, the western part of the Red Desert area (Ts. 20-22N.; Rs. 95-97 W.) was mapped in reconnaissance. No coal

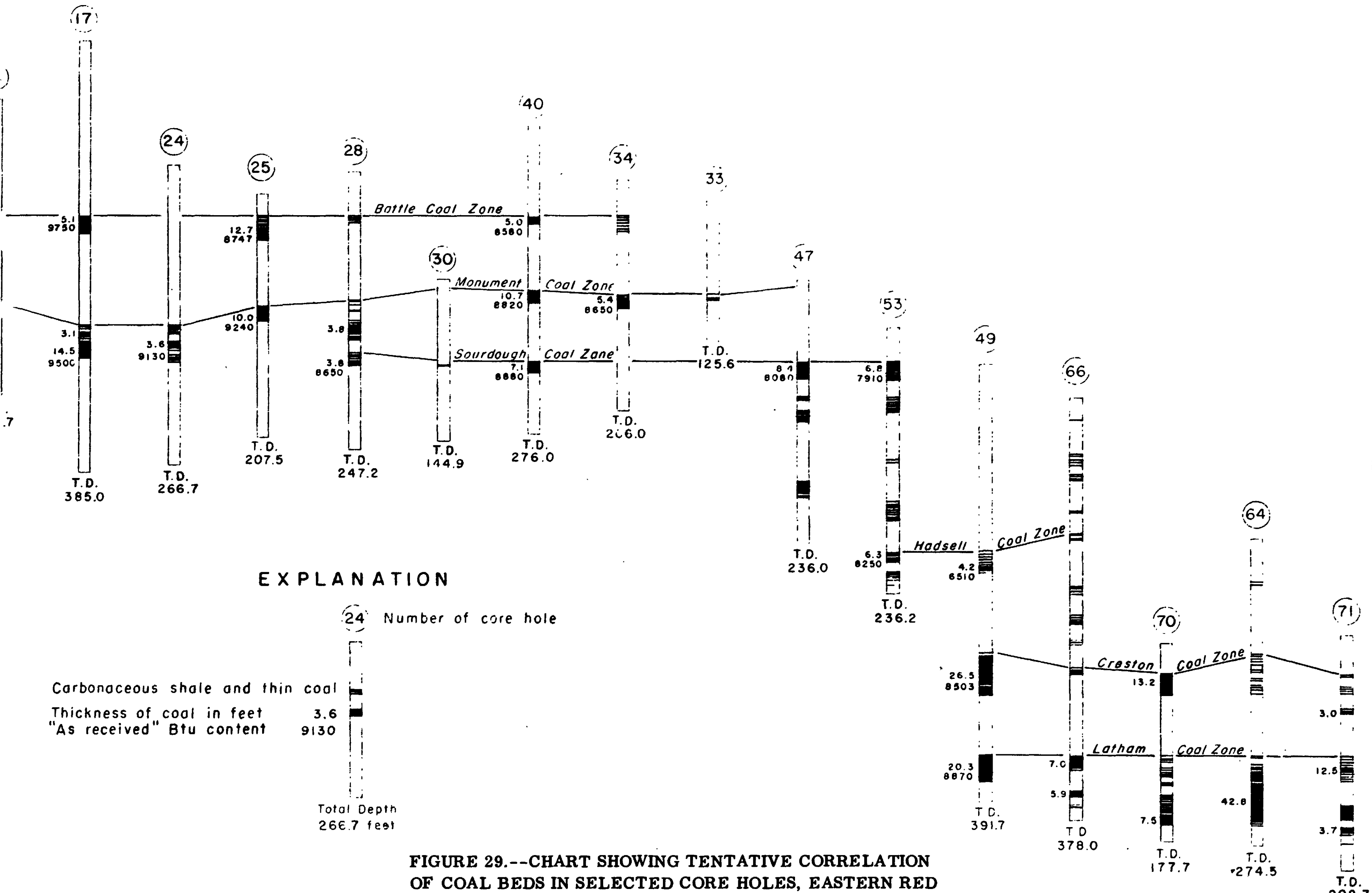


FIGURE 29.--CHART SHOWING TENTATIVE CORRELATION OF COAL BEDS IN SELECTED CORE HOLES, EASTERN RED DESERT AREA, SWEETWATER COUNTY, WYOMING 1953

beds were found thick enough to be of economic interest. Geiger counter and scintillator readings indicate that the coal samples submitted for analyses will contain an average of 0.002 percent U, or less.

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

Core drilling in the Fall Creek area, Bonneville County, Idaho, was started in June and completed in August, 1953. The drilling was planned to search for possible high-grade deposits near faults that may have controlled access of uranium-bearing water to carbonaceous shale and limestone in the Bear River formation of Lower Cretaceous age and to sample the uranium-bearing strata (Vine, Circ. 212).

Six holes totalling 1,618 feet were completed. (See figs. 30 and 31). The structure of the area is much more complex than was anticipated and only two of the holes penetrated the radioactive carbonaceous shale. The data available from drilling is, therefore, inadequate to revise the estimate of uranium-bearing rock previously submitted (TEI-310, p. 148).

Analyses of samples submitted from holes 1 and 2 are shown below:

Sample No.	eU (percent)	U (percent)	Ash (percent)	U in ash (percent)	Thickness of sampled interval	Lithology
			Drill hole No. 1			
VI-1300	0.003	0.003	-	-	0.6'	Limestone
1301	.003	.004	-	-	1.0'	"
1302	.003	.003	-	-	1.0'	"
1303	.007	.007	-	-	1.0'	"
1304	.013	.014	-	-	1.0'	"
1305	.020	.028	77.1	0.036	1.2'	Carb. sh.
		Core loss			1.3'	?
1306	.025	.036	70.0	.056	0.5'	Carb. sh.
1307	.023	.028	69.0	.039	1.0'	"
			Drill hole No. 2			
1308	.006	-	-	-	0.9'	Carb. sh.

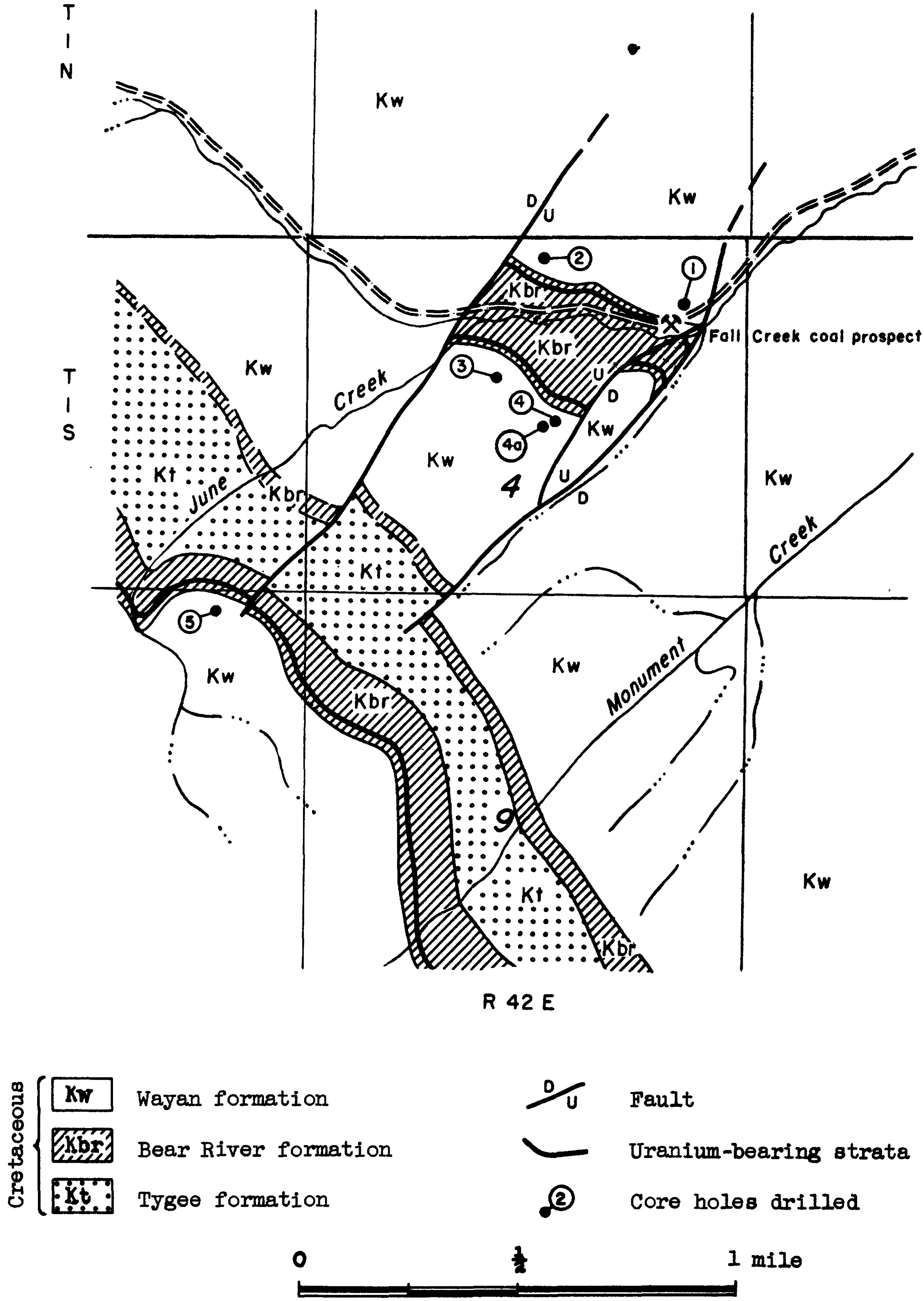


FIGURE 30.--SKETCH MAP SHOWING LOCATIONS OF CORE HOLES TESTING URANIUM-BEARING STRATA, FALL CREEK AREA, BONNEVILLE COUNTY, IDAHO

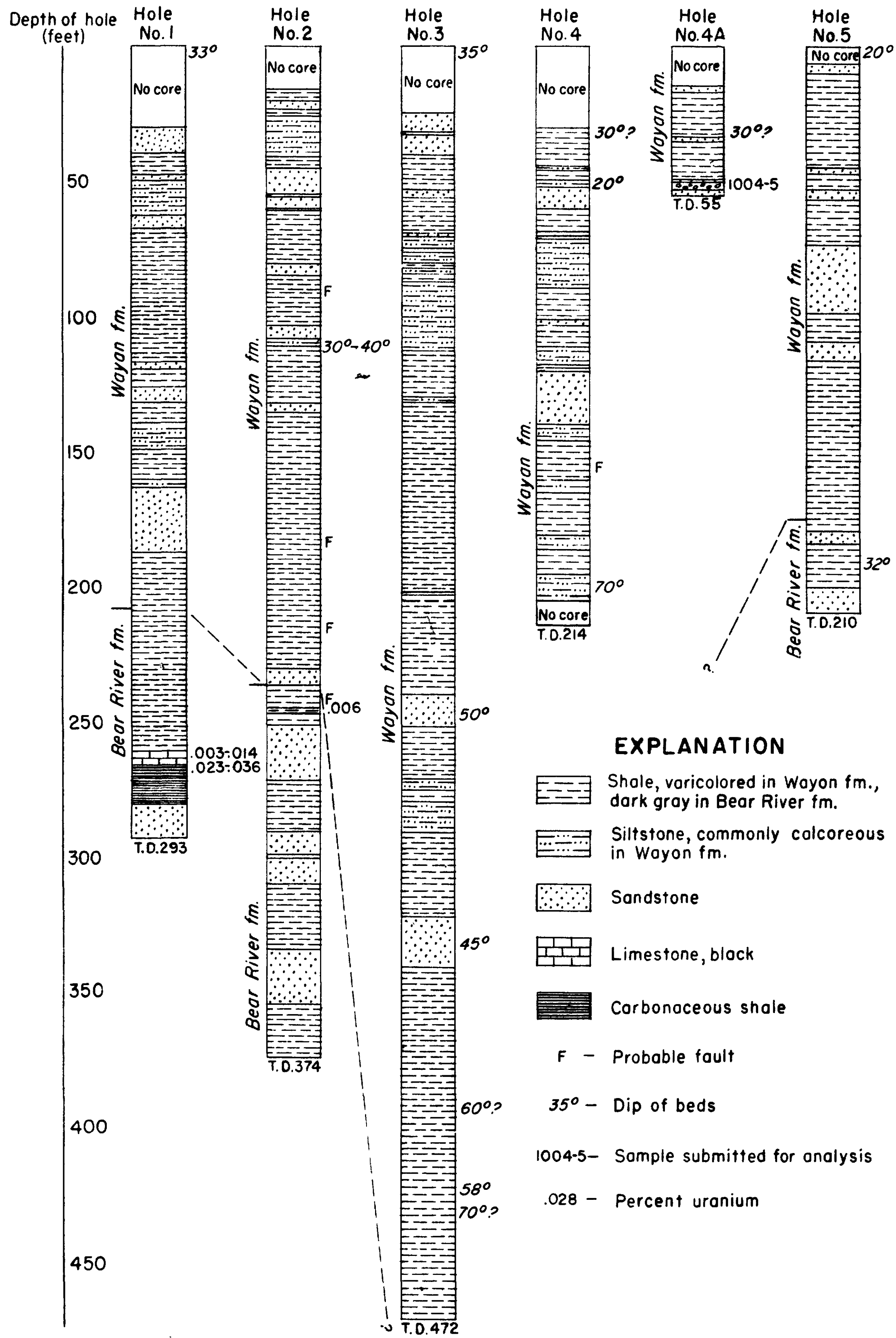


FIGURE 31.--STRATIGRAPHIC SECTIONS OF CORES FROM FALL CREEK AREA, IDAHO

Black shale investigations

Chattanooga shale, by L. C. Conant

The drilling program in the Chattanooga shale by the Bureau of Mines has been finished. It consisted of 36 closely-spaced holes near Smithville, Tennessee (the Youngs Bend area) and 28 widely-spaced holes (25 in Tennessee, 3 in Alabama). Seven other holes, requested by the Bureau of Mines, have been drilled at Sligo and Pine Creek, near Smithville, to test mining conditions.

Plans for the immediate future are (1) to complete the logging and sawing of the cores, (2) to prepare reports on the areas thus far drilled, and (3) to extend geological investigations into areas where basic geologic information on the shale and its uranium content may be obtained.

Mineralogy, petrology, and geochemistry

Lignite core processing
by J. M. Schopf, R. J. Gray and J. C. Warman

Core from twenty-five holes drilled in exploration for uraniferous coal has been received at Columbus for processing. Core from a few most recent holes now is on hand to be studied and receipt of core from one additional 8 inch diameter hole is anticipated. A list of materials processed and sampled is given in Table 5.

Radioactivity estimates and laboratory descriptions have been supplied the field geologist, analytic laboratory, and administrative offices for all core as soon as they could be made available. The radioactivity estimates were given as pulses (counts) per minute per gram of

Table 5.--Tabulation of Core and Related Materials
Examined at Columbus

Location, Project & Hole	Linear ft. of Core Received	Lab Samples =Radioactivity Determinations	TE Analytic Samples	B of M Analytic Samples
Dakota				
Slim Buttes Hole SD-8	37.9	86	10	4
" " Auger Hole K-26	13.5	21	10	2
Wyoming				
Red Desert RWC Hole 12	15.9	22	4	1
13	46.9	81	41	1
16	38.9	62	16	2
17	55.7	125	29	3
24	33.3	64	25	2
32	14.6	35	4	2
33	13.7	27	6	-
34	29.9	69	26	1
40	49.3	101	5	3
43	39.1	79	4	2
46	23.0	33	18	-
49	130.5	263	57	7
50	41.3	64	11	1
53	107.6	107	19	3
58	19.8	28	4	-
63	59.3	114	9	2
64	100.8	194	11	5
Cores received and now in process of study				
66	55.0			
68	64.8			
70	54.3			
71	70.0			
Idaho				
Goose Creek Hole 2	35.0	60	32	1
Goose Creek Hole 3A	4.0	7	-	-
Miscellaneous samples				
Western Virginia Black Shale	-	25	3	-
Burnet County, Texas Black Shale	-	6	1	-
Washington coal	-	22	-	-
Totals	1154.1	1695	345	42

sample (P/M/G). Comparison of P/M/G numbers with uranium chemically determined suggests that these measurements are relatively consistent with few exceptions (e.g., P/M/G numbers on highly pyritic samples are too low), and that one P/M/G unit is usually equivalent to about 30 parts per million U. Actual comparison, based on the averages of 35 samples most recently reported, shows 1 P/M/G corresponds with 28.7 parts per million U.

Although accuracy declines at low count rates the laboratory equipment is sensitive enough to give significant duplication of results on samples containing less than 10 ppm U. P/M/G determinations have been relied on as a basis for selection of samples to be submitted for more accurate analysis. All samples exceeding 1.5 P/M/G have been submitted; other series of samples, representing minable thicknesses and averaging more than 1 P/M/G, also have been sent to Trace Elements laboratory for further study.

Active drilling in the Slim Buttes area finished early in July so that only one core (SD-8) and a series of auger samples (K-26) were processed. Radioactivity measurements showed a thin layer at the top of the uppermost bed or Mendenhall Rider to be the most radioactive coal received at the Coal Geology Laboratory from Dakota. The P/M/G value for this layer was 31.8 and suggests a uranium content of about .09%. Unfortunately a considerable core loss directly below this layer prevents any accurate appraisal based on this record. An auger hole was drilled at a nearby site to further test uranium content of this upper coal. Diagrams illustrating the radioactivity profile of Hole SD-8 and of the auger hole are shown in figure 32. The auger samples, although showing signs of weathering, appeared little contaminated and contained about 12 percent ash for a composite sample of the entire top bench. A very characteristic

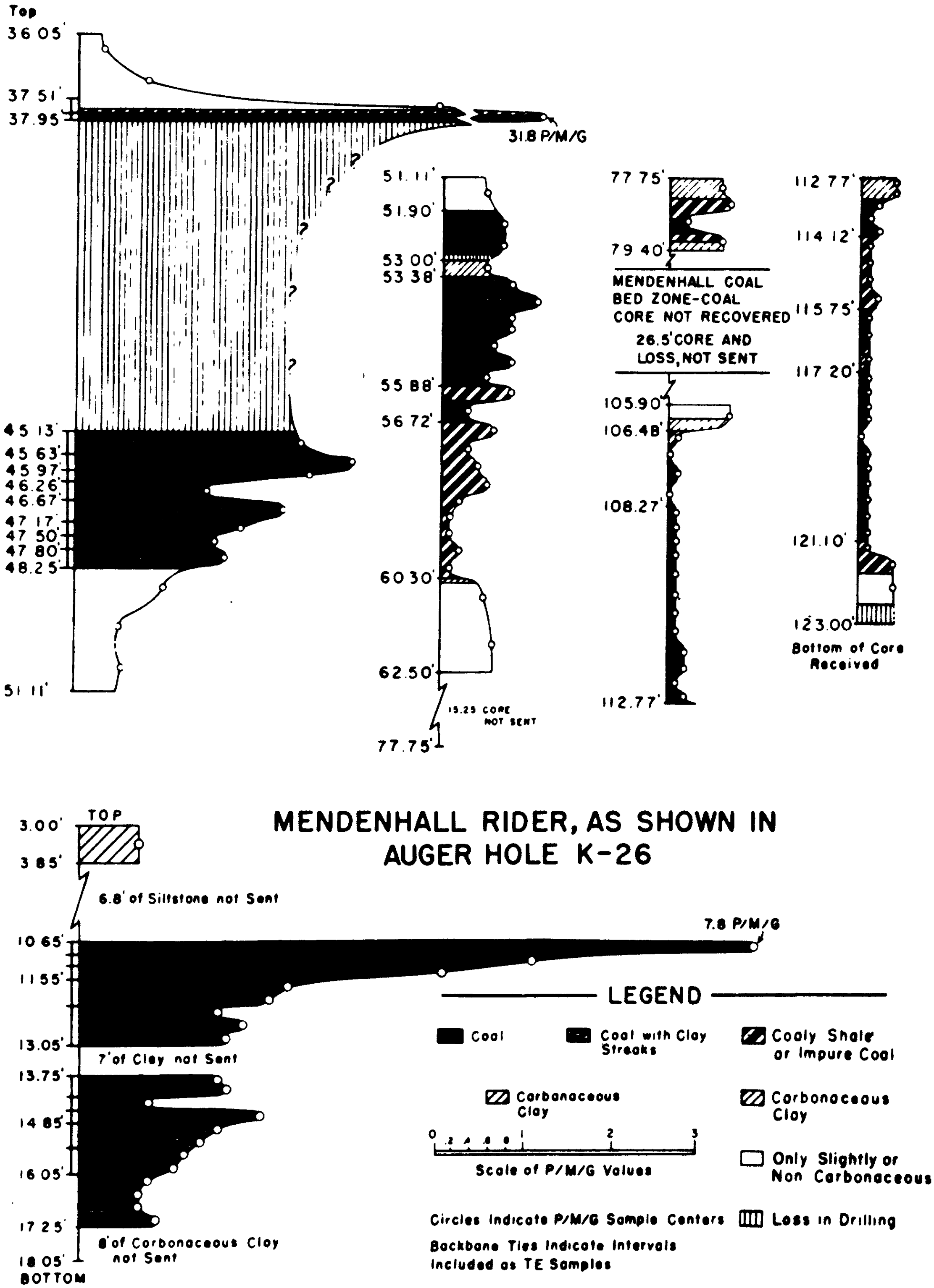


FIGURE 32.--RADIOACTIVITY PROFILE SLIM BUTTES AREA, HARDING CO., SOUTH DAKOTA MENDENHALL RIDER AND LOWER COAL BEDS IN HOLE SD-8

top preferential distribution of radioactivity is illustrated but the exceptional value for the upper layer of Hole SD-8 was not equalled. It thus appears that the unusually high value probably is local in its extent.

Most of the core received for processing at the Coal Geology Laboratory came from the Red Desert drilling program. All Red Desert cores examined showed much irregularity in distribution of radioactivity. This has come to be recognized as being as characteristic of Red Desert profiles as a top preferential distribution is characteristic of radioactive coals in the Dakota region. Very frequently peaks of greater radioactivity are associated with more or less well-defined layers of detrital impurity. To what extent this relationship may prevail should be indicated by coal petrographic investigations planned for completion during the next year.

Radioactivity profiles of probable correlative sections of core, including two coal beds and associated carbonaceous and coaly rocks from the Battle zone as tested by Holes 17 and 24, are shown in figure 33. The comparison illustrates well the considerable variability that is typical. The two actual coal beds probably are more or less continuous but it seems evident that the coaly or impure layers that show the highest radioactivity differ materially within short distances. Some of the purer coal appears to be no more radioactive than slightly carbonaceous silty or sandy beds of the same area.

Figure 34 shows the radioactivity profile established for the extensive and slightly older Tierney group of coals tested in Hole 49, located about seventeen miles SSE of holes 17 and 24 shown in the previous figure 33. Evidently the distribution of radioactivity is similar to that in the somewhat younger coals to the northwest but the average level

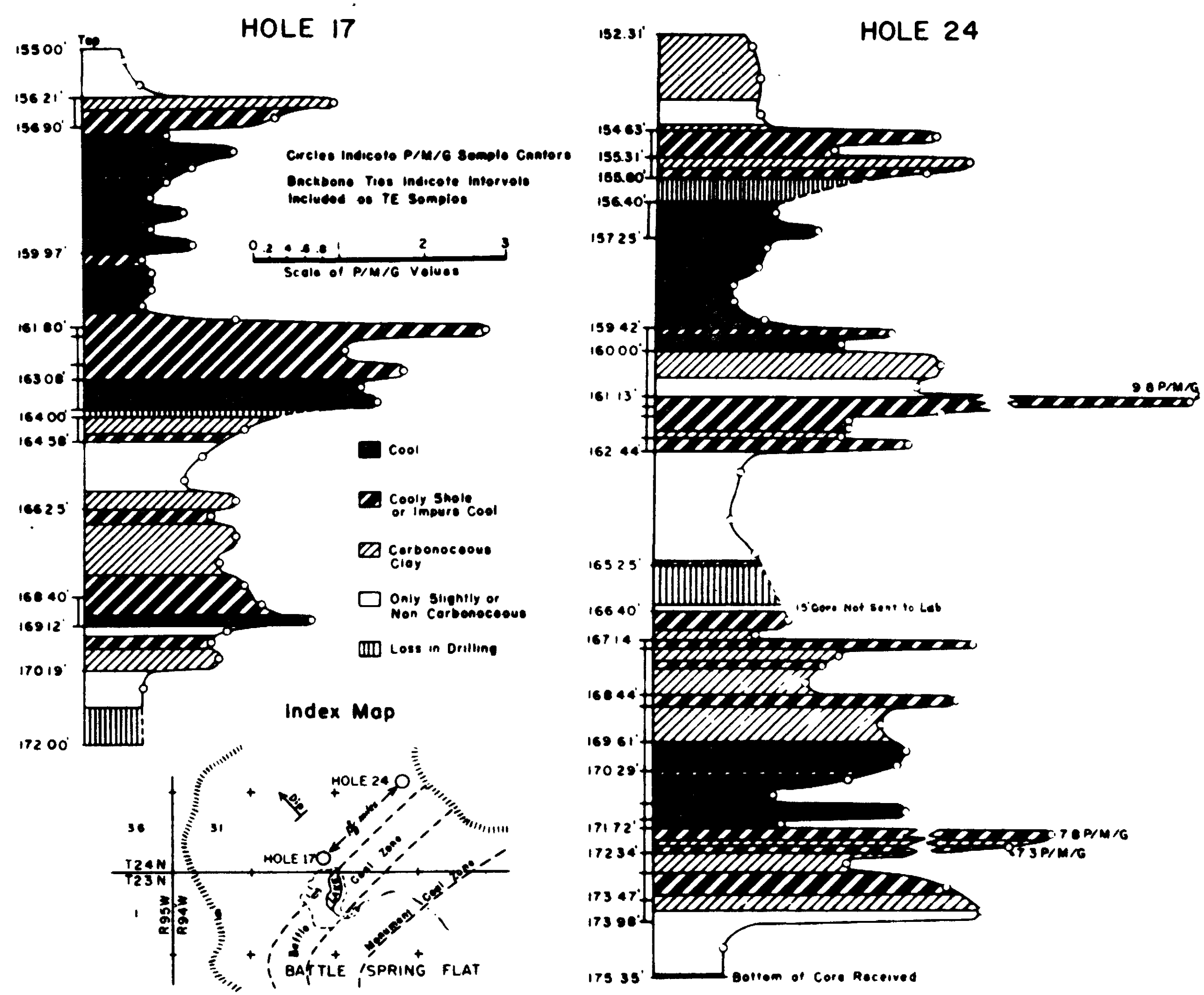


FIGURE 33.--CORRELATED RADIOACTIVITY PROFILE BATTLE COAL ZONE IN BATTLE SPRING FLAT, RED DESERT AREA SWEETWATER CO., WYOMING

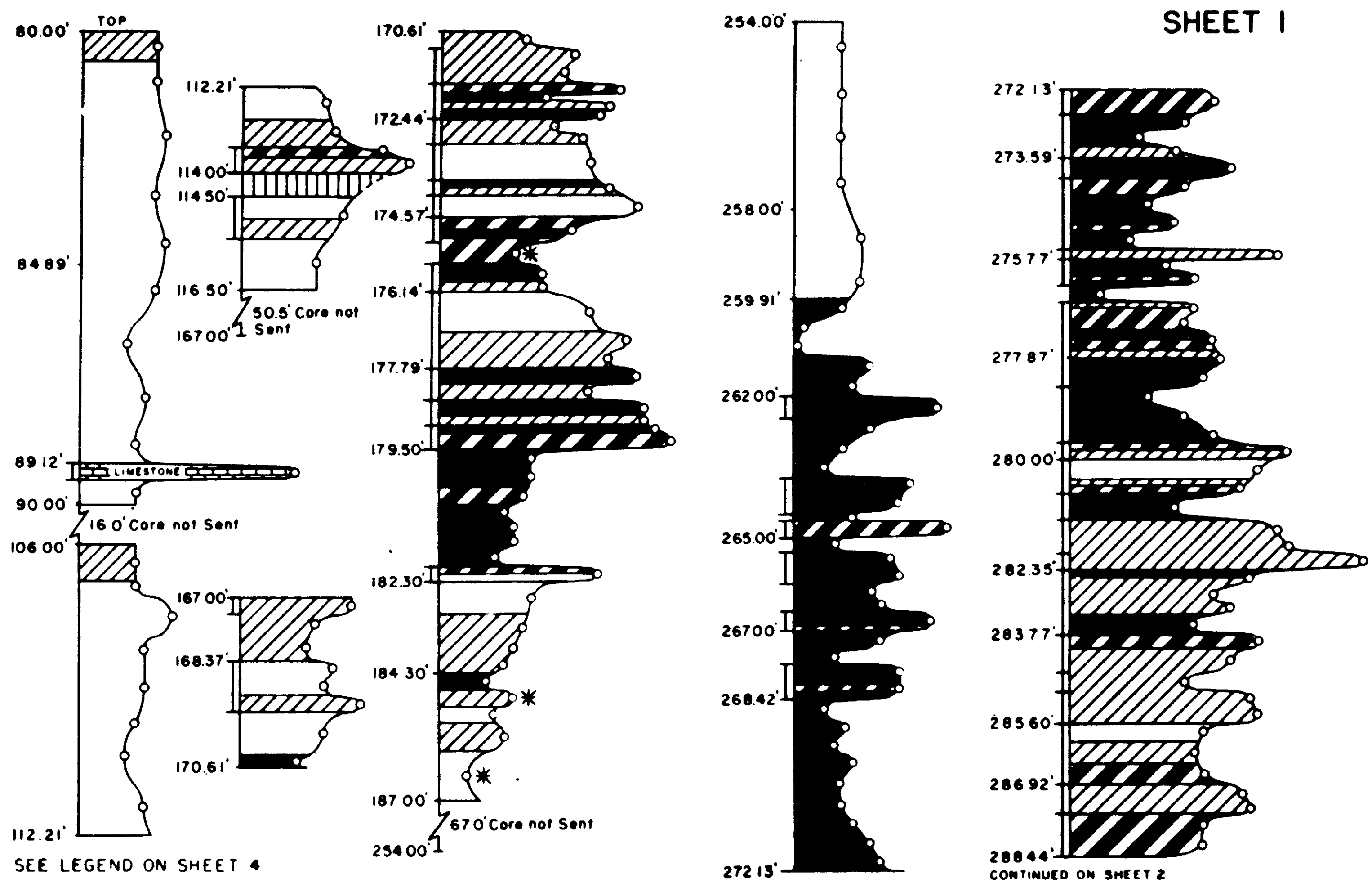


FIGURE 34.--RADIOACTIVITY PROFILE INCLUDING TIERNEY COAL ZONE HOLE 49, RED DESERT AREA, SWEETWATER CO., WYOMING LOCATED ABOUT 17 MILES SSE OF HOLES 178.24, AND 7 MILES NW OF CRESTON

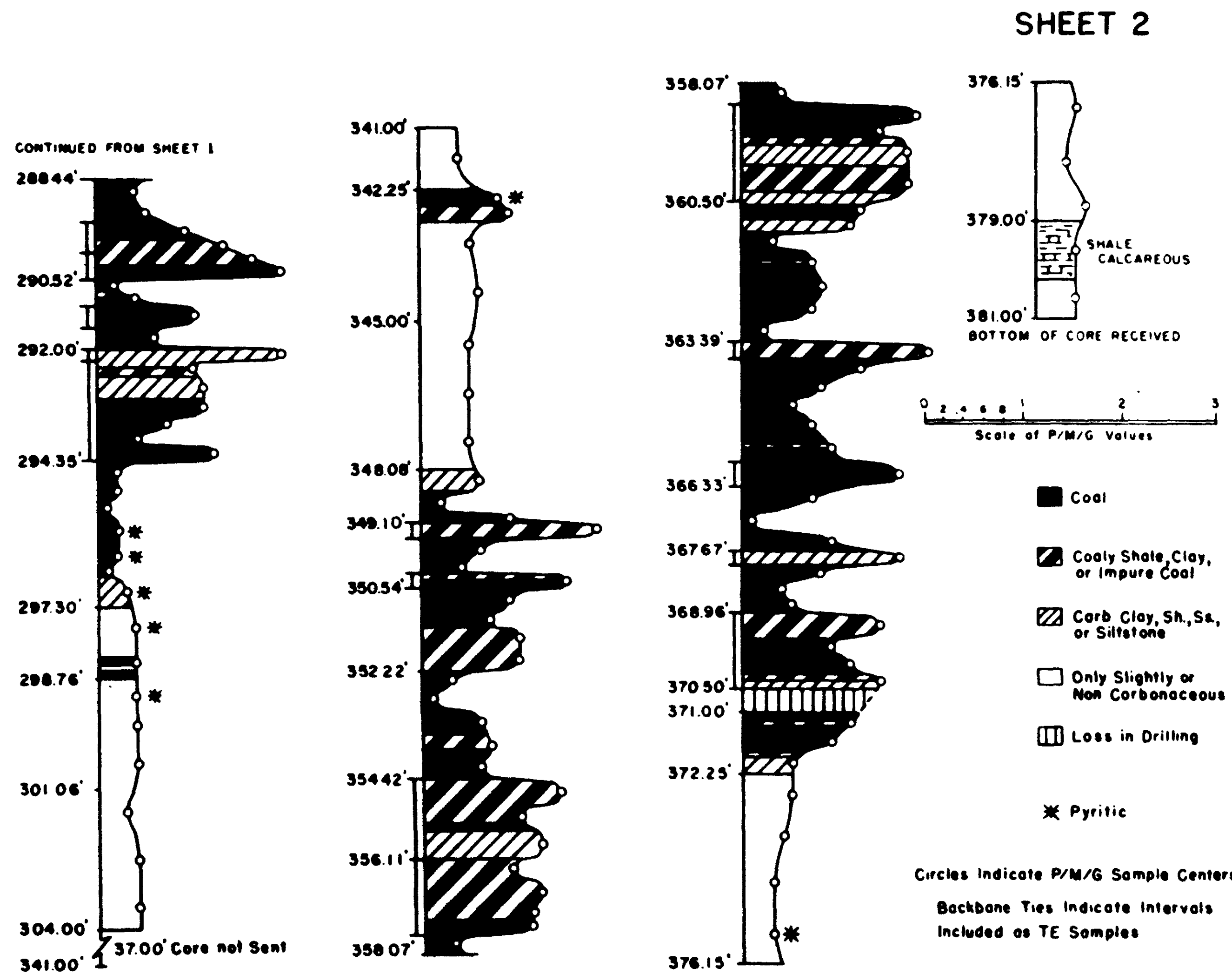


FIGURE 34.--HOLE 49, RED DESERT

of radioactivity is lower. Some of the coal is considerably less radioactive than the non-carbonaceous field rock and usually only the impure carbonaceous layers indicate a higher value.

A core 8 inches in diameter has been obtained from the Luman coal zone in the northern part of the Red Desert field where exploration during the 1952 season suggested greatest economic possibilities. A core of these dimensions should afford an excellent opportunity for a correlated suite of analytic investigations and coal petrographic research. These studies will aid in determining how the uranium of these extensive deposits may best be made available.

Core showing promise of economic uranium recovery was received from the Goose Creek district of southern Idaho. The radioactivity profile from this core is illustrated in figure 35. Peaks in the zone of greatest radioactivity are drawn with several overlapped and differently cross-hatched patterns so that their full relative extent may be visualized.

The coaly zones are nearly all attrital and distinguished by high radioactivity. They are fissile to some extent and thus may easily be confused with black shale since they also merge with obvious carbonaceous shale and clay. Like most attrital or non-banded coals the Goose Creek deposits are probably high ash. A suggestion of top and bottom preferential radioactivity is suggested by the lower coaly zone below depth of 260.7 feet.

A series of miscellaneous black shale samples of paleontologically defined age were examined by procedures similar to those applied to core. A series of Preliminary Reconnaissance Reports has been submitted recording the detailed results. Samples of Upper Devonian age from Texas appear to be somewhat more radioactive than samples of known uranium content and similar lithology from Tennessee.

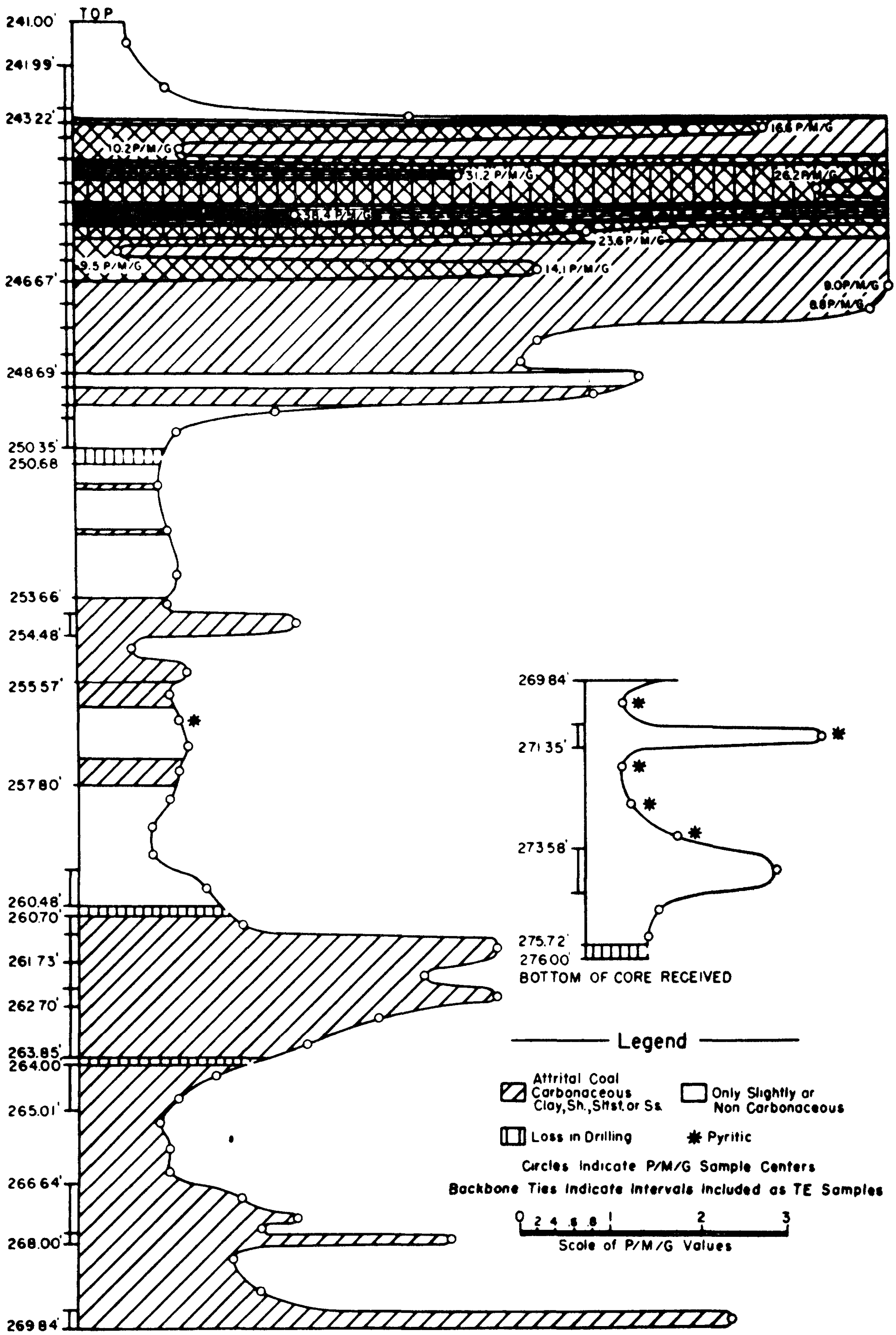


FIGURE 35.--RADIOACTIVITY PROFILE GOOSE CREEK IDAHO, HOLE 2

A series of coal specimens from beds associated with tuffaceous deposits in the State of Washington were examined and proved to be essentially non-radioactive.

Coal petrography
by J. M. Schopf and R. J. Gray

Uraniferous lignite in the Slim Buttes area, South Dakota, usually shows very definite, more or less regular, top-preferential distribution of uranium. Each of three beds of lignite in Hole SD-10, however, contain as much or more uranium in thin layers at the bottom or in the middle of individual beds as in the top layers of the bed. Standard coal petrographic studies were made of these three beds to detect differences, if any, between the composition of the highly uraniferous lignite where the uranium was concentrated in positions other than at the top of the bed. The data are shown graphically in figure 36.

The lignite beds in Hole SD-10 differ greatly among themselves in petrographic composition. No correlation between uranium content and standard coal petrographic constituents can be seen. The ash content shows an increase somewhat comparable to the uranium content in several of the more uraniferous layers.

The possible correlation between different microscopically visible plant materials and degradation products and uranium was investigated by a detailed study of the components of the translucent attritus of four samples from Hole SD-10 containing from 0.015 to 0.037 percent uranium and of four samples containing from 0.0003 to 0.002 percent uranium. The following components were distinguished in the translucent attritus: sub-anthraxylon; humic matter; red attrital resins; spores, pollens, and

SHEET 1

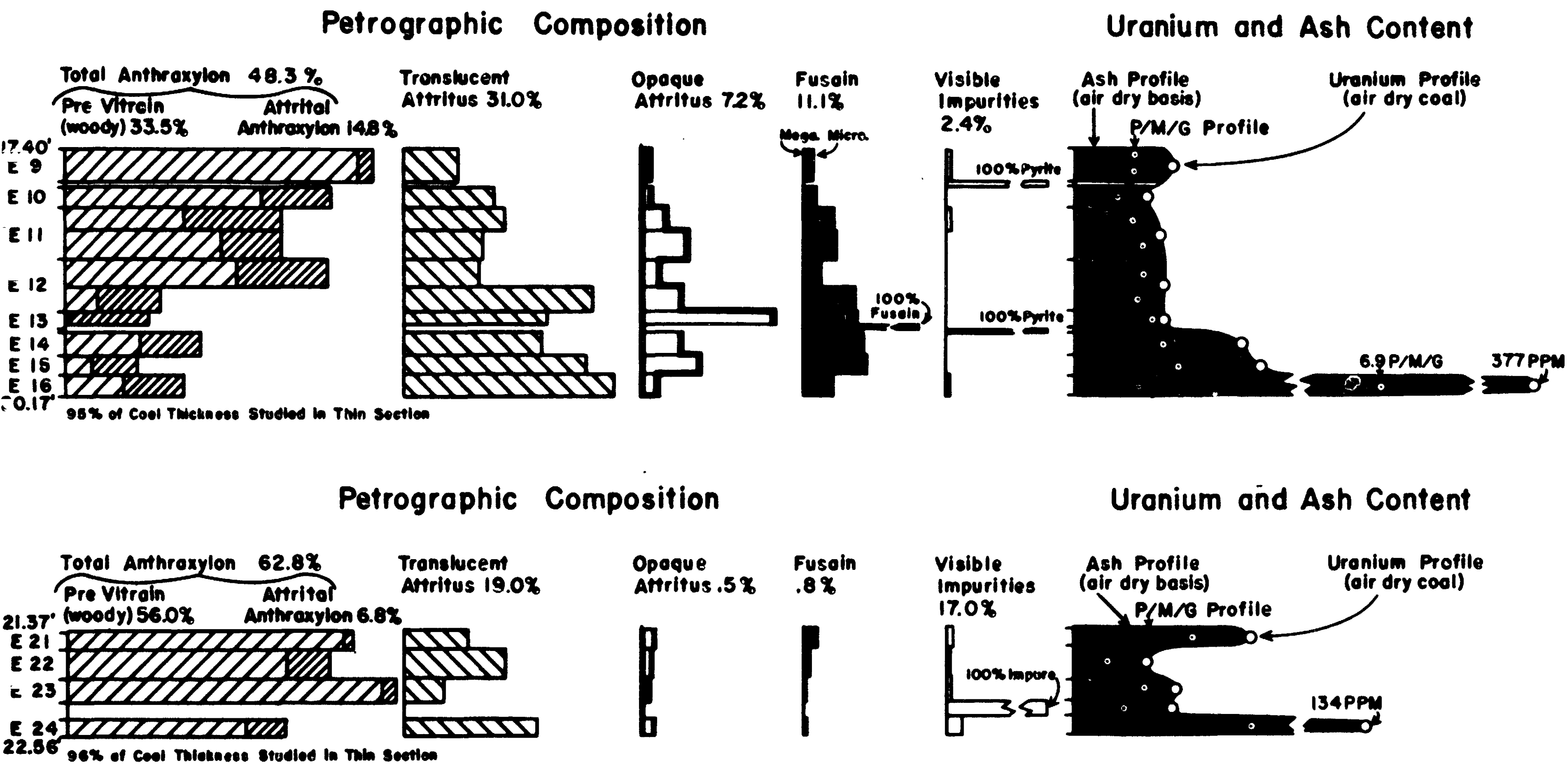


FIGURE 36.--PETROGRAPHIC COMPOSITION OF COALS IN DRILL HOLE SD-10 SLIM BUTTES AREA, HARDING COUNTY, SOUTH DAKOTA

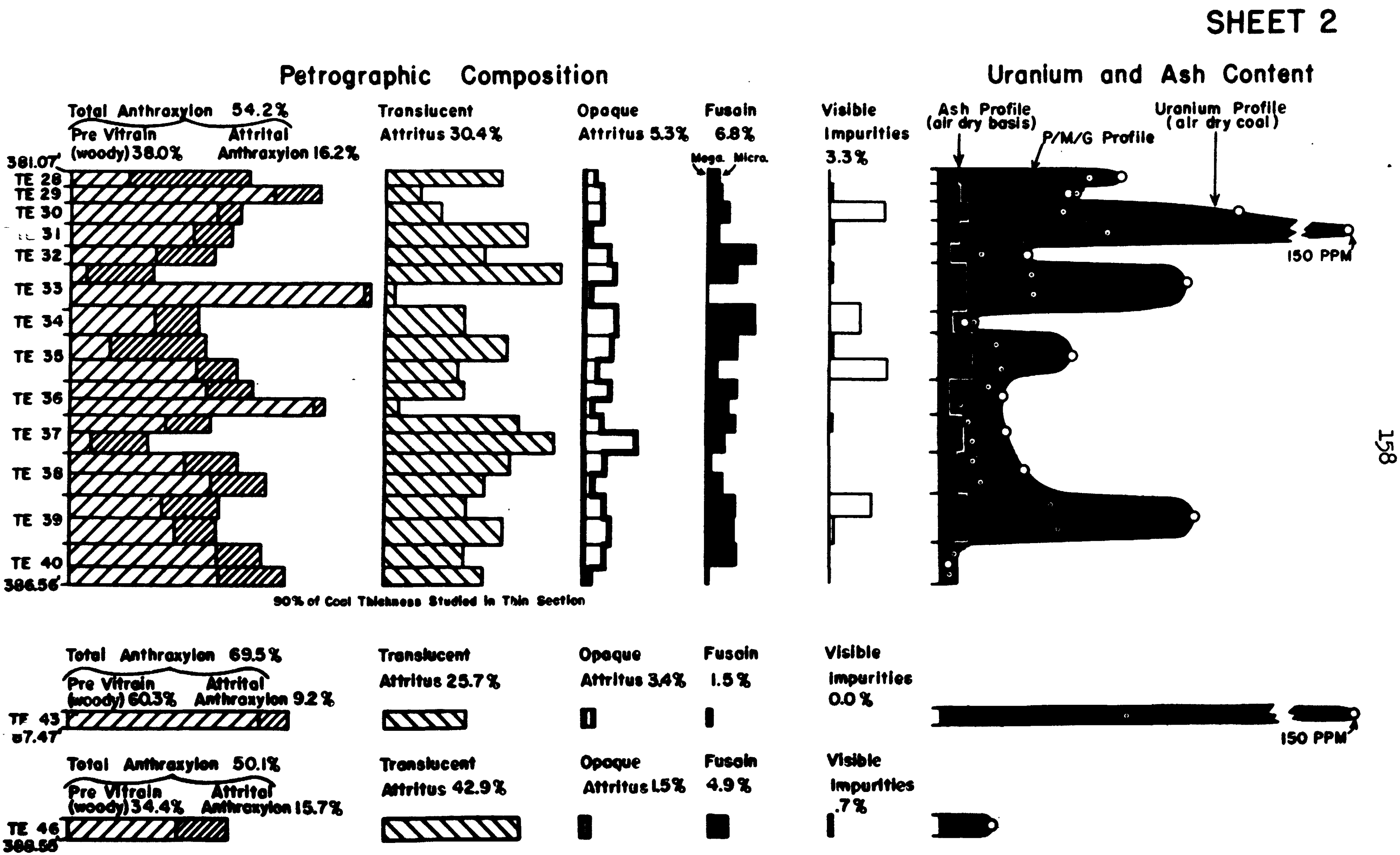


FIGURE 36.--SD-10

cuticle; yellow attrital resins; waxy amorphous material; transparent organic material, fungus spores and fungal sclerotia; and brown matter with traces of semi-fusain fragments. No direct correlation was found between any single coal component and uranium content. If it is assumed that the uranium in all of these samples is combined with the organic material or taken up by it in the same way, which remains to be proved, then a more complex correlation of factors appears to be responsible for the variations in uranium content. Apparently none of the samples owe their high or low uranium content to their relative positions within the beds.

It may be significant that some layers with high uranium content also have comparatively large amounts of humic matter and fungus material. As the humic matter is largely the product of extensive decay, it is conceivable that plant material that has been most subjected to decay is the most receptive to uranium emplacement. This relationship holds only in some samples, so extensive decay can be only a predisposing factor.

Uranium in lignite and coal
by I. A. Breger and M. Deul

During the report period, progress has been made in the various phases of this program as follows:

Lignite from Harding County, S. Dak.--Large scale extractions of the coal have been carried out with samples containing both high and low percentages of uranium. A preliminary experiment reported previously (TEI-331) indicated that it was possible to isolate and concentrate the organo-uranium complex responsible for the retention of the uranium in the coal. The technique applied in the original study has been followed and a large quantity of the organo-uranium complex has now been isolated and awaits characterization by physical and chemical techniques.

Formation of uraniferous coals.--The proximity of schroeckingerite to uraniferous subbituminous coal in the Red Desert suggests that uranium may have been introduced into the coal by way of a solution containing sodium and calcium uranyl carbonates. The low pH (3.1) of the Red Desert coal and the reported sensitivities of sodium and calcium uranyl carbonates to decomposition in acidic media also suggest that the uranyl ion, on release from the complex carbonate, may form an insoluble compound with certain organic components of the coal.

To examine this hypothesis, organic matter has been extracted from both South Dakota and Red Desert coals which contain very little uranium. These extracts will be reacted with solutions of schroeckingerite in an effort to prepare organo-uranium concentrates for comparison with organo-uranium extracts from high-uranium-bearing coals. This study will provide information regarding the nature of the organo-uranium compounds in coal and the manner in which they are formed.

Effects of retorting on the uranium associated with coals, shales, and other substances.--Small samples of coal from the Red Desert, of Chattanoooga shale, and of Swedish kolm have been retorted and, by means of careful analytical studies, it has been found that no uranium volatilizes during distillation. After the Red Desert coal is retorted, extraction of uranium from the char by 6 N hydrochloric acid becomes difficult. It is possible that during distillation under reducing conditions part of the uranium may have been converted to UO_2.

<u>Organo-uranium associations in the Colorado Plateau region</u>.--During a field trip to the Colorado Plateau, samples of coalified wood, so-called "asphaltite," bituminous sandstone, and so-called "bleeding asphalt" were collected in sufficient quantities for characterization. Studies by which it is hoped that it may be possible to determine the relationship of the uranium to these various organic substances will soon be initiated.

Infrared spectrophotometry has been applied to a structural analysis of soluble organic material extracted from ore grade sandstone from the Utex mine. Yellow, resinous material has been recognized from its infrared spectrum as being terpene in nature. It is likely that this material is of woody origin.

The following reports are in preparation: "Mineralogy and geochemistry of uraniferous coal from the Red Desert area, Sweetwater County, Wyoming"; "Extraction of uranium from the Red Desert coal of Wyoming"; "Effects of destructive distillation on the uranium associated with selected naturally occurring carbonaceous substances"; and "Minor and trace elements in low-rank coals".

Uranium in black shales
by I. A. Breger and M. Deul

Studies of the organic substances present in black shales have continued. Preliminary investigations have been concerned with efforts to isolate mechanically the organic and inorganic constituents of the Chattanooga shale.

The original shale (75.5 percent ash, 0.0085 percent U) was subjected to air elutriation in an Infrasizer and yielded a fraction containing 70.0 percent ash and 0.0143 percent U. Subsequent efforts have been made to isolate the organic matter by air elutriation techniques using the Aminco Roller elutriation equipment. Fractions from this work await analysis.

Small samples of Chattanooga shale have been treated in a ball mill with mixtures of kerosene and water in an effort to bring about selective suspension of organic components in the kerosene. While this technique has proved partially effective, recent use of other organic suspending agents has made it possible to effect nearly complete separation of the shale into organic-, pyrite-, and clay-rich fractions. Chemical analyses of these fractions are now being carried out and a report summarizing these studies should be completed by the end of the current fiscal year.

Marine, uranium-bearing carbonaceous shales in the Phosphoria formation are of special importance to this project because of their association with uraniferous phosphorite. Because the organic substances present in phosphate rock may be easy to isolate and characterize and because organic material present in the shale and in the phosphate rock may be similar, studies of the phosphate rock have been initiated. To date a program has been outlined and work has begun on the isolation, with least chemical alteration, of the organic material in the phosphate rock.

A small sample of organic stringer from the Chattanooga shale has been found to contain only 1.27 percent ash. Analysis of this ash shows it to contain 2.58 percent U and approximately 4 percent germanium. A preliminary report describing this newly observed occurrence of germanium and association of germanium and uranium will be submitted in the near future.

Relationship of color of shale to uranium content
by F. J. Flanagan

The qualitative observations of field geologists, that the amount of uranium in black shale appears to be a function of the color is the subject of a current study. As the color of an object is a result of the absorption of some wave lengths of light and the reflection of others, a simple measurement of the value of light reflectance (without regard to wave length) is a measure of the value of a single color and this measurement may then be compared to the uranium content or the radioactivity of the shales. This density of reflected light is measured in a reflection fluorimeter which has been modified by funnelling white light (in place of ultra violet) onto the surface of shale samples in aluminum pans normally used in radioactivity determinations.

An entire suite of samples from one drill hole (YB-6) in the Youngs Bend area in central Tennessee was selected and the density of light reflection measured. A comparison of the means of the uranium content and the radioactivity of ten holes in this area and the reciprocal of the light reflected measured in microamperes for the above suite of samples if shown in fig. 37. The agreement between the one sample of reflection and the means of the uranium content and the radioactivity is very good. Further work is in progress. The method, if feasible, may be a satisfactory rapid method for the determination of uranium in shales. Measurements on Chattanooga shale from different areas, and on other types of shale are necessary to determine whether or not the method is applicable to all shale deposits. It may be possible to extend this procedure to the measurement of the uranium content of low-grade carnotites and northwestern phosphates.

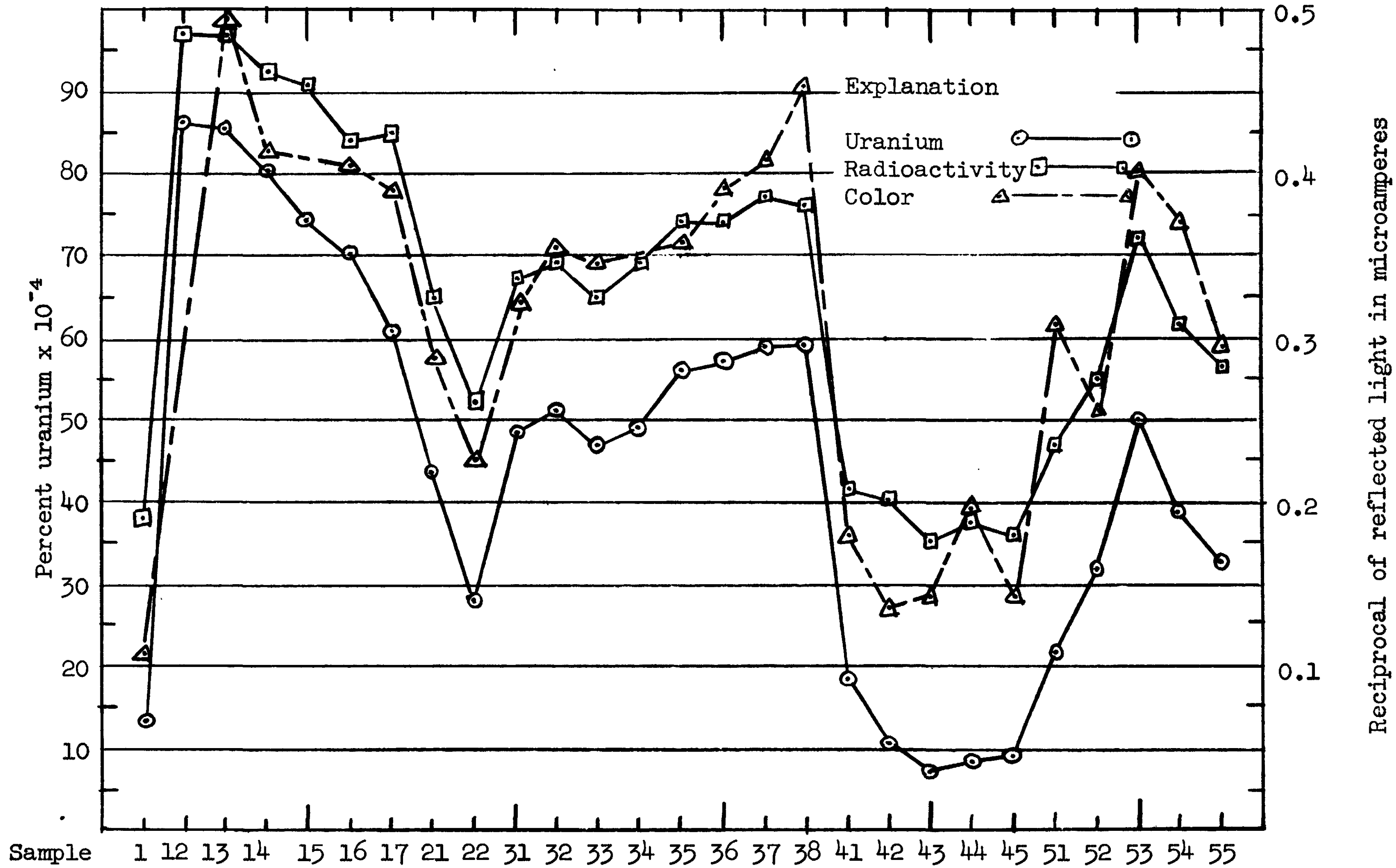


Figure 37.--Comparison of uranium content, radioactivity, and color value of some Chattanooga shales.

Uranium in asphalt and petroleum

During the period covered by this report, a total of 190 analyses were made on 135 samples of crude oil, petroliferous rock, and brine associated with oil. A distribution of these analyses and samples in shown in Table 6.

Table 6.--Distribution of Sample Types and Types of Analyses

Sample Type	No. of Samples	Type of Analysis	No. of Analyses
Petroliferous rock	46	% Ash	70
Crude Oil	87	% U in Ash	52
Brine	2	% U (other than ash)	26
		% Oil (in rock) 1/	32
		Other 2/	10

1/ The % Oil is the percent material extracted from rock with hot 75% benzene, 15% acetone, and 10% absolute methanol by volume.

2/ Includes specific gravity, total solids, and organic carbon.

Improved procedures have been worked out in the laboratory for the sampling and ashing of crude oils and asphaltites. Modification of the ASTM D482-46 method for ashing petroleum oils by the incorporation of an oxygen atmosphere in the electric muffle has reduced to one-fourth the time formerly required for the final ignition of the ash.

At the present time a study of ashing methods is also being made to resolve the problem of losses which may occur during the burning of the sample by volatilization and/or mechanical entrainment. Duplicate samples of a group of crude oils from ten different oil fields are being ashed by two methods, i. e., "dry" ash and wet oxidation. From the data acquired in this study further improvements in ashing and subsequent analysis will result. In addition, important information on the loss of metals during ashing will be gained. An extension of this study to include "fly ash" will be undertaken in the near future.

The petroliferous materials in rocks are first subjected to an extraction to remove their soluble fraction. After this extraction is completed, the extracted portion is ashed. A similar technique is applied to solid asphalts to remove any particles of contaminating material.

Ash samples obtained by the above treatments are analyzed chemically for uranium and by semi-quantitative spectrographic methods for other elements. In the near future chemical analyses will be made for several metals other than uranium. The uranium analysis is made by the fluorimetric method (Circular 199, Grimaldi, May, and Fletcher).

A report of the early work accomplished by the project has been made in TEM-513, "The Association of Uranium and Other Metals with Crude Oils, Asphalts, and Petroliferous Rocks", by Erickson, Myers, and Horr. This report has been submitted for publication in the AAPG.

URANIUM IN PHOSPHATES

Northwest phosphate

by V. E. McKelvey and others

Regional geologic mapping

Several important areas previously unmapped or mapped at small scales are being mapped geologically to provide data on the distribution and structure of the phosphate deposits and on other mineral resources and geological problems. The areas include the four $7\frac{1}{2}$-minute quadrangles comprising the Willis No. 2 quadrangle, the four comprising the Willis No. 3, one (the SW) of the $7\frac{1}{2}$-minute quadrangles of the Willis No. 4, Montana; another (the NE$\frac{1}{4}$ of the SW$\frac{1}{4}$) of the Dell, Mont.; the four 15-minute quadrangles (Nos. 1-4) comprising the Lyon quadrangle, Mont.; and parts of the Virginia City and Eldridge quadrangles, Mont.; the Centennial Mountains phosphate district; the Soda Springs 15-minute quadrangle, Ida.; and six $7\frac{1}{2}$-minute quadrangles in the Aspen Range-Dry Ridge area of Idaho.

Field work is completed, except for checking, in all of the Montana areas except the Lyon No. 1 quadrangle. Aside from some work on map and report compilation none of these projects were active during the past six months and only the status of work in the Willis No. 2 and the Lyon quadrangles is summarized below. Mapping of the Johnson Creek and Dry Valley $7\frac{1}{2}$-minute quadrangles in Idaho is completed and final reports went forward for publication during the summer. Work in the Soda Springs quadrangle was recessed in 1951. Mapping of the Stewart Flat and Snowdrift Mountain quadrangles is in progress.

The Lyon Quadrangles, Mont., by G. C. Kennedy

Three 15-minute quadrangles, the SE$\frac{1}{4}$, the SW$\frac{1}{4}$ and the NW$\frac{1}{4}$ of the Lyon 30-minute quadrangle, were mapped between 1947 and 1952. The NE$\frac{1}{4}$ has been started but probably will not be completed.

The area includes parts of the Centennial Valley, the Centennial Mountains, and the Gravelly Range. The rocks exposed include members of every system from the pre-Cambrian to the Tertiary except the Ordovician. Most of the Paleozoic and early Mesozoic sequence is composed of carbonate rocks, sandstone, and red beds but the Cretaceous and Tertiary rocks contain many conglomerates, arkoses, and tuffaceous beds. Basalt and rhyolite flows are interbedded with the Tertiary rocks.

The Permian Phosphoria formation crops out in both the Centennials and Gravellys but only the Centennials appear to contain valuable deposits. There the lowermost unit of the formation contains four to five feet of highly phosphatic rock, much of which lies at shallow depths.

The Willis No. 2 quadrangles, Mont., by W. B. Myers

Field investigation of pre-Cambrian Belt rocks in the SW quadrangle showed that their stratigraphy is more varied than previously thought and new detailed mapping has thrown much light on their structure and has yielded new data on their composition. A hitherto unrecognized facies of carbonatic fine-grained sediments, including a few layers of pure calcite marble, was found in a sequence previously thought to be largely quartzite and entirely free of carbonate.

Seemingly contradictory observations on the sequence of the various plutonic igneous rocks have been confirmed by further investigation. The accumulated data may point to conclusions of general application regarding the evolution of certain granitic rocks.

In the 1953 field season fourteen stratigraphic sections involving the complete formations were measured and described. In addition, several partial sections have been measured and described and a large number of representative samples taken. Further field investigation and collection from the upper Jurassic (?) and lower Cretaceous suggest that fine pyroclastic material may be common and at some horizons predominant. New data suggest a possible algal origin in lakes or ponds of volcanic environment for much of the lower limestone member of the Kootenai formation.

The new workings of the major lead-zinc producer within the quadrangle, the Mauldin mine, and various workings of the French Creek group of gold mines have been mapped this season and several smaller workings have been examined and described.

Snowdrift Mountain quadrangle, Idaho, by E. R. Cressman

About 27 square miles, approximately half of the Snowdrift Mountain 7½-minute quadrangle, were mapped at a scale of 1:12,000 during the 1953 field season. The area is the southwest quarter of the Crow Creek quadrangle mapped previously by Mansfield (Prof. Paper 152, 1927, pl. 7) at a scale of 1:62,500.

Pre-Tertiary rocks in the quadrangle range in age from Mississippian to early Cretaceous and total approximately 8,500 feet in thickness. They have been divided into 19 mapping units. The Cenozoic deposits are tentatively being mapped in eight units. The structure consists of several north-northeast trending folds in the Carboniferous, Permian, and Lower Triassic rocks and a north-northeast trending zone of thrusts near the eastern margin of the quadrangle that have brought the older formations in contact with Jurassic and Lower Cretaceous strata.

One new outcrop of the phosphatic shale member of the Phosphoria formation was located, although it is probably too small to be considered for mining, and the outcrops of the formation as shown by Mansfield have been modified in several places.

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

Approximately 15 square miles of the Stewart Flat quadrangle have been mapped at a scale of 1:12,000. The area includes the major portion of the southwestern quarter and three east-west traverses across the quadrangle. This quadrangle comprises the northwest quarter of the Crow Creek quadrangle, previously mapped by Mansfield at a scale of 1:62,500.

Over half of the quadrangle is underlain by the Georgetown and Webster synclines, which plunge gently to the north. The youngest rocks exposed in these synclines belong to the lower portion of the Thaynes formation of Triassic age. Thus the Phosphoria formation of Permian age is present at depth over a large portion of the quadrangle.

In order to gain depth control on the Phosphoria formation considerable attention has been paid to the stratigraphy of the immediately overlying Dinwoody formation of lower Triassic age. A section of the Dinwoody at South Stewart Canyon was measured in 1949 and a section at Diamond Creek was measured in 1951. The correlation between these two sections was determined this season by walking outcrops, and four mappable units were delineated.

Phosphate rock of possible economic value was found in the upper shale member on the east limb of the Webster syncline. The upper shale member is overlain by the easily strippable claystone member of the Dinwoody formation and the beds in the area dip about 20° west. These deposits will be investigated further.

Geology of the Johnson Creek quadrangle, Idaho, by R. A. Gulbrandsen, K. P. McLaughlin, F. S. Honkala, and S. E. Clabaugh

The $7\frac{1}{2}$-minute Johnson Creek quadrangle in southeastern Idaho has been mapped at a scale of 1:12,000 for publication at 1:24,000. Only sedimentary rocks occur in the quadrangle; formations present are the Brazer formation of Mississippian age, the Wells formation of Pennsylvanian age, the Phosphoria formation of Permian age, and the Dinwoody and Thaynes formations of Triassic age. Rocks of Tertiary and Quaternary age have not been named.

The Johnson Creek syncline and the Aspen Range anticline are the principal structural features of the quadrangle. They trend west of north and are modified and partially obscured in places by many minor folds and by faults that have broken the area into large and small blocks. Most of the faults strike parallel to the trend of the folds though a few are normal to it.

Phosphate rock occurs as bedded rock in different horizons in the Phosphoria formation. There are two principal zones of economic importance; one near the base of the formation about 20 feet thick, and a five-foot zone about 100 to 150 feet above the lower zone. Phosphate is being mined currently by the Anaconda Copper Mining Company.

Geology of the Dry Valley quadrangle, Idaho, by E. R. Cressman and R. A. Gulbrandsen

The $7\frac{1}{2}$-minute Dry Valley quadrangle in southeastern Idaho was mapped at a scale of 1:12,000 for publication at 1:24,000. Only sedimentary rocks are exposed in the quadrangle. Paleozoic formations are the Brazer limestone of Mississippian age, the Wells formation of Pennsylvanian age, and the Phosphoria formation of Permian age. Mesozoic strata are represented only by the Dinwoody and Thaynes formations of Early Triassic age. Unnamed Tertiary and Quaternary strata overlie Paleozoic and Mesozoic formations unconformably.

The most prominent structural feature of the quadrangle is the Schmid syncline, a relatively simple, open fold with both the north and south ends plunging gently toward the center. Most of that party of Dry Ridge included within the quadrangle is underlain by the moderately-dipping strata forming the east limb of the Dry Valley anticline. These beds are thrust east into the Georgetown syncline, a tightly-folded structural feature that is slightly overturned to the east.

The phosphate mineral, cryptocrystalline carbonate-fluorapatite, occurs in quantity in the phosphatic shale member of the Phosphoria formation. Two zones of phosphate rock in the member, one at the base and the other about 20 feet below the upper contact, are suitable for mining. Mining activity is restricted to the Dry Ridge area where the Western Fertilizer Association is removing overburden on the ridge immediately south of the Canyon preparatory to stripping.

Reconnaissance in the Philipsburg-Maxville-Drummond area, by R. W. Swanson

The phosphatic shale in the Philipsburg-Maxville-Drummond region is 9 to 20 feet in thickness and contains a phosphate zone at the top that ranges from 3 to 7 feet in thickness and, because of the presence of mudstone partings, probably contains 27-28 percent P_2O_5. The rocks appear to be rather extensively weathered, which may favorably affect their beneficiation.

Weathering and enrichment of phosphate, by L. D. Carswell

Information from a few of the deeper workings in the western field suggest that the high-grade phosphate beds may contain 2-5 percent more P_2O_5 in weathered than unweathered sections. Four areas in the Bear River region where both underground and surface exposures are available have been selected for study of this problem. Others will be studied later when some of the underground workings now contemplated by mining companies are completed or extended.

Preliminary qualitative analysis of these sections suggest (1) the phosphate content is higher in moderately weathered zones than in unweathered zones, but (2) the phosphate content in areas where the rocks lie below the pre-Wasatch erosion surface is slightly higher at moderate depths than at the surface, suggesting that some phosphate as well as other constituents may have been leached out during this long-continued erosion interval, and (3) underground samples are higher in uranium than surface equivalents.

Southeast phosphate
by R. G. Petersen

Exploration

Company drilling

The following company drilling on land to be mined prior to 1965 has been carried out under contract with the AEC:

	Holes drilled		Footage		
	Last report	Total to date	Last report	Total to date	Percent completed
Swift & Co.	10	43	420.0	1,604.7	100
Coronet Phos. Co.	0	73	0	2,358.3	100
American Agricultural Chemical Co.	0	43	0	1,740.5	30
American Cyanamid Co.	Drilling to begin about December 8, 1953.				

The companies are collecting samples from the aluminum phosphate and calcium phosphate zones and analyzing them for U, P_2O_5, Al_2O_3, and CaO. The Geological Survey's gamma-ray logging unit has been logging every hole.

The routine collection of company prospecting samples to be analyzed for U has continued at a rate of about 1,000 samples per month.

Geologic drilling

A total of 115 holes for 6,796 feet have been drilled on lines radiating from the edge of the economic phosphate district. These holes were logged and sampled and a gamma-ray log taken on each hole. This program has been completed and a report is being prepared.

Mobile drilling

A Mobile drill and the gamma-ray unit have been used for exploratory drilling and for blocking out areas of high grade uranium.

Radiometric logging of drill holes

From June 1 to November 30, 1953, a total of 406 holes aggregating 18,513 feet were logged by the gamma-ray unit. The cumulative total for the gamma-ray unit is 2,971 holes totalling 105,188 feet.

Reserve appraisal

Calculation of the tonnage and grade of uranium in the leached zone is continuing and should be completed by April 1, 1954.

Geologic studies

As reported in the last semi-annual report, several projects have been set up to study the geology and economics of the Florida land-pebble phosphate field and the geology of the adjacent surrounding territory. The following are progress summaries of these projects written by the several project chiefs (see fig. 38):

Economic geology, land-pebble phosphate district, by J. B. Cathcart

A preliminary report on the "Economic geology of the aluminum phosphate zone in the Peace River area" will be transmitted in January.

The report shows, by means of maps and diagrams, the distribution of the aluminum phosphate zone, and the variation in P_2O_5, U, CaO, and Al_2O_3, both laterally and vertically in the area. The area is divided into three physiographic provinces, (1) the ridge, (2) the flatwoods, and (3) the valley and floodplain of the Peace River. The aluminum phosphate zone is thickest, most continuous, and highest in P_2O_5 and U in the flatwoods region, and is thin and discontinuous, or absent in the ridge area, and is absent in the floodplain and valley of the Peace River. Analytical maps indicate that areas of high P_2O_5 and high U generally correspond, and in general these high areas correspond with the thicker sections. However, detailed drilling has shown the extreme lateral variations in both thickness and analyses, from possibly mineable to unmineable areas in as little as 200 feet. It also seems possible that fairly uniform feeds can be maintained for weeks at a time. It seems likely that very detailed drilling will be necessary prior to mining in order to predicate feeds for a plant, and that some surge capacity and mixing facilities will be necessary to maintain a uniform feed.

For the next six months work will continue on the aluminum phosphate zone for the entire land-pebble area. Data on distribution and tonnage and grade of the zone should be completed and a draft of a

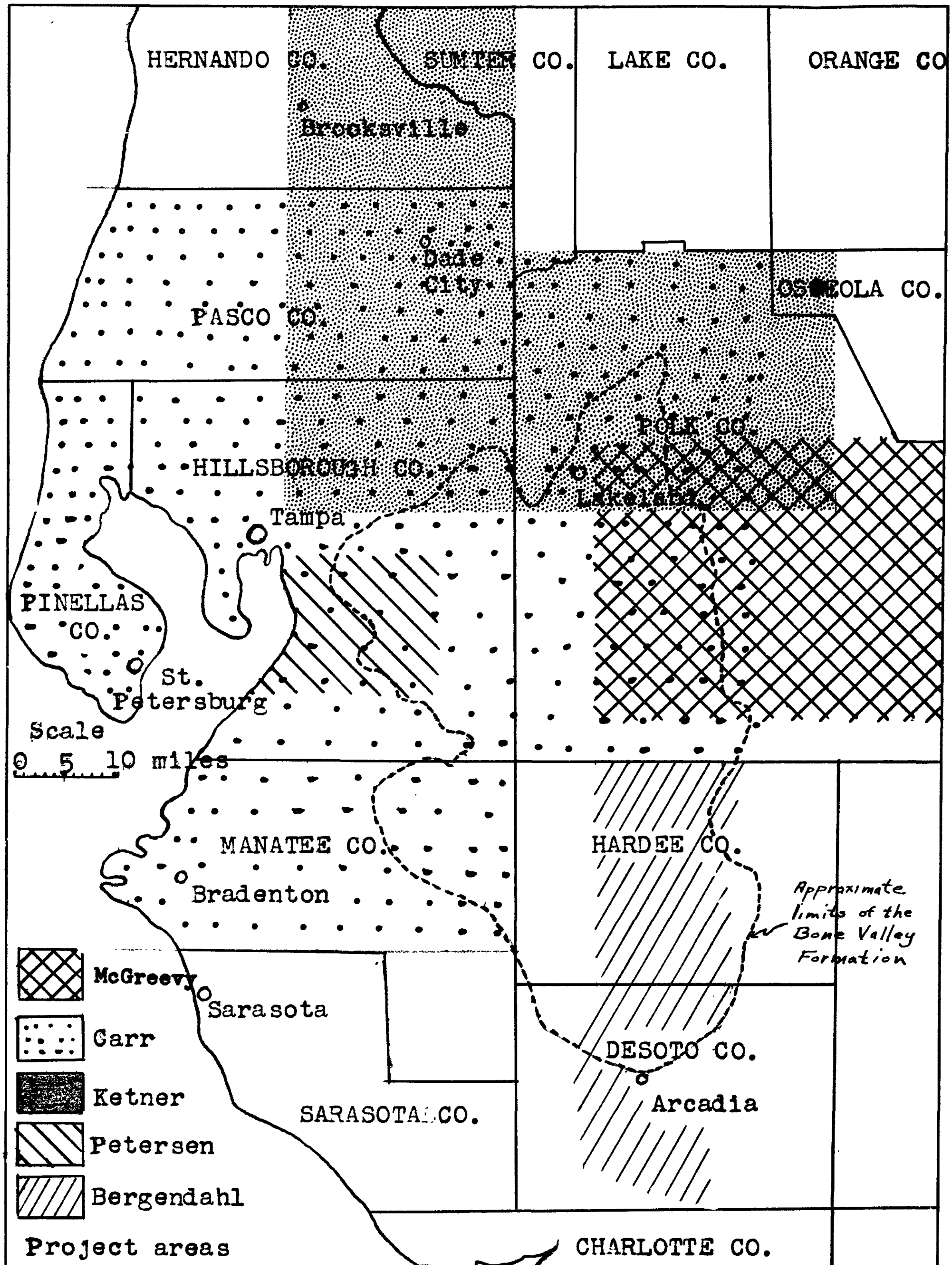


FIGURE 38.--MAP SHOWING PROJECT AREA, FLORIDA PHOSPHATE DISTRICT

preliminary report on the aluminum-phosphate zone should be completed by the end of the next reporting period.

Geology of Parts of Hardee and De Soto Counties, Florida, by M. H. Bergendahl

The objectives of this project are as follows:

1. To determine the southernmost limits of the Bone Valley formation and its stratigraphic relations with formations to the south of the land-pebble phosphate district.

2. To locate concentrations of radioactive material.

The area under investigation is shown in fig. 38. Field work was begun in April, 1953. During June and part of July, a total of 92 holes were drilled with a truck-mounted power auger. As outcrops in the area are restricted to stream banks and shallow pits, this drilling was necessary to obtain more detailed stratigraphic information. Locations of holes are shown on Fig. 39. All holes were logged and sampled. In addition to the holes drilled by the power auger, lines 10 and 11 of the AEC contract geologic drilling program extended into this area.

The following interpretations are indicated by the field evidence to date:

1. A calcareous sand containing upper Miocene shells and phosphate sand underlies the Caloosahatchee formation and extends several miles northward from the northernmost Caloosahatchee exposure. This sand grades northward into an unfossiliferous phosphatic sand. Occasional lenses of calcareous clay are present. This unit does not contain economic phosphate. Underlying the upper Miocene sand is a soft gray to buff limestone containing phosphate sand. It is probably the Hawthorn formation.

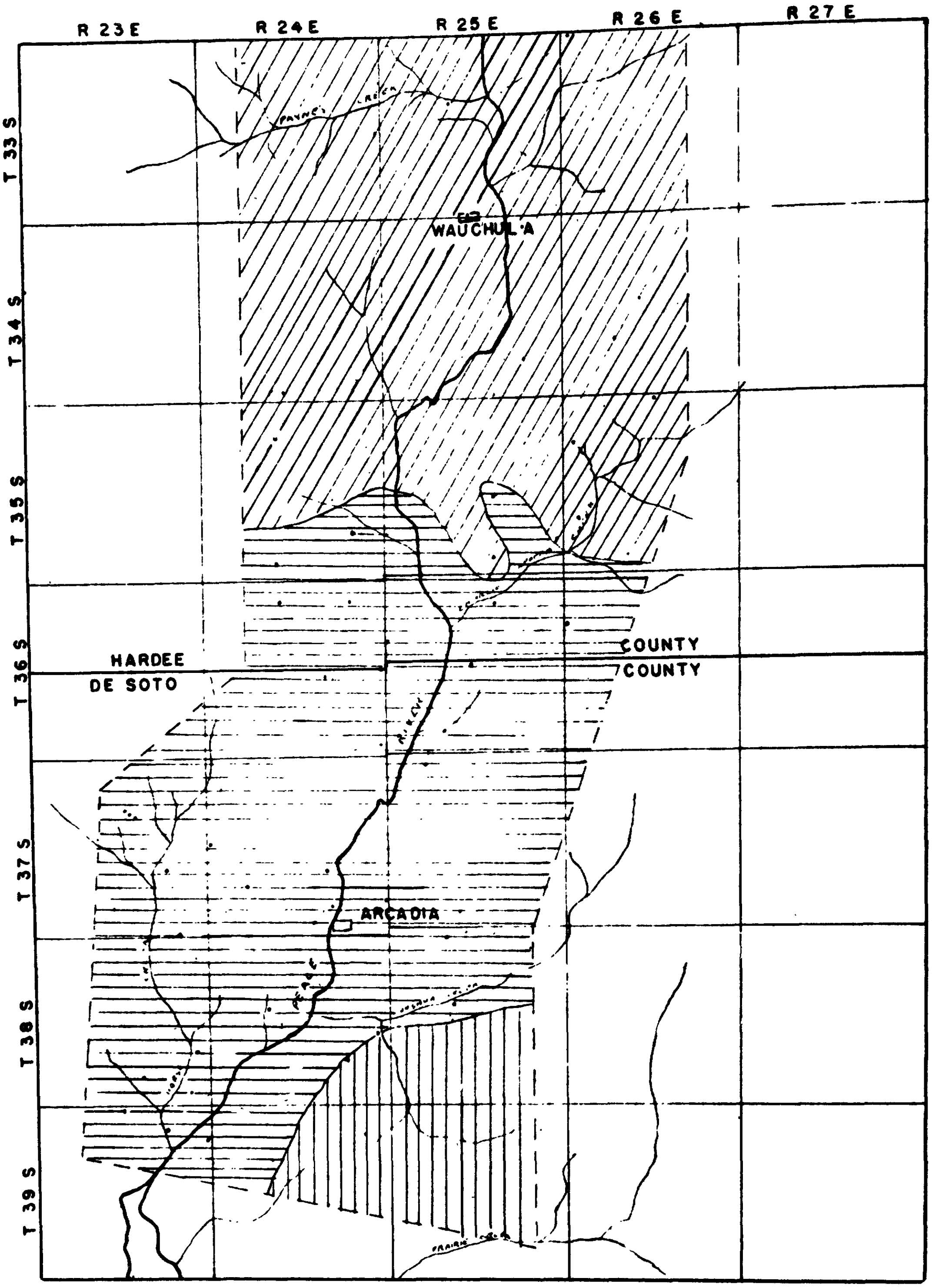
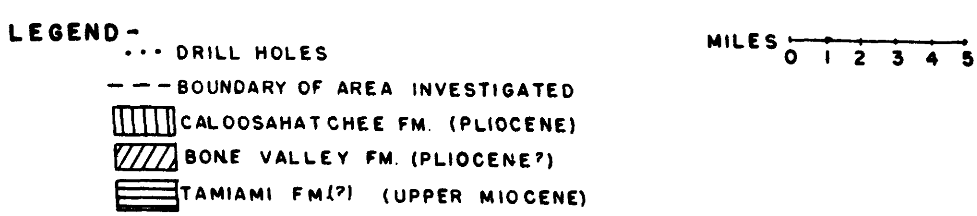


FIGURE 39.--SKETCH MAP OF LATE CENOZOIC GEOLOGY. SURFICIAL SANDS AND CLAYEY SANDS NOT SHOWN



2. The northern limit of the Caloosahatchee and southern extent of the Bone Valley formations are definable (Fig. 39).

3. The stratigraphic relations between the Bone Valley and Caloosahatchee formations are obscure.

4. Unconformably overlying the Bone Valley, Tamiami (?) and Hawthorn formations is a well-bedded clayey sand and sand, containing varying amounts of phosphate sand. At several localities a conglomerate composed of phosphate cobbles is present at the base. It is presumably a flood-plain deposit of late Pliocene or Pleistocene age. The phosphate does not occur in economic concentrations.

5. The lithology of the Bone Valley formation changes toward its southernmost limit. The phosphate sands, gravels, and clays, typical of the economic district to the north, appear to be of lower grade in this area. At its southern margin, the Bone Valley formation is composed of blue-gray clay and clayey sand, containing moderate amounts of phosphate sand and pellets. The leached zone is thin, poorly developed, and absent in many places.

Stratigraphy of Suwannee, Tampa, and Hawthorn formations in Hillsborough and parts of adjacent counties, Florida, by W. J. Carr and D. C. Alverson

Field work.--During 3 months field work from April to July 1953 about 100 exposures, many previously unknown, were visited and most were sampled. Fossil collections were made at previously undescribed outcrops. Two of the best exposures of Tampa limestone were mapped in detail, and one of these has been tentatively designated as a type locality for that formation in west-central Florida.

Forty holes of the geologic core drilling program were logged in detail and samples of calcareous material collected, and several hundred driller's and geologist's logs of wells in west-central Florida were obtained from the Florida Geological Survey at Tallahassee.

Laboratory and office work.--In August, 45 samples for thin-sections, 11 for X-ray mineral determinations, 51 for semi-quantitative spectrographic analysis, and 65 for chemical analysis for U, P_2O_5, CaO, Al_2O_3, Fe_2O_3, and MgO were submitted to the Survey laboratory. Sixty samples of fossils were submitted to paleontologists for age determinations and more than 100 insoluble residues from the limestones have been obtained by acidulation. The results of all analyses to date have been plotted on a triangular diagram, the members of which are soluble material, sand, and silt and clay. Mechanical analysis by screening of the sand-size residues and raw samples of non-calcareous beds has been started. Cumulative curves are being drawn and statistical parameters computed therefrom.

The preliminary base map of the area, scale 1:250,000, has been prepared and location and elevation of exposures, mines, and drill holes have been plotted. Available topographic coverage for the area has been compiled and is being plotted on the base map with a contour interval of 40 feet. Cross-sections are being prepared with data from drill holes, well logs, and exposures.

A preliminary draft of the manuscript is about half completed.

Conclusions: depositional environment and lithology.--Study of the Tampa (lower Miocene) and Hawthorn (middle Miocene) limestones indicates that both were deposited in a shallow-water, near-shore marine environment favorable to formation of phosphate. The Tampa limestone especially shows features of near-shore deposition. The Suwannee limestone (Oligocene) was deposited in deeper water well removed from sources of sediment.

Work with insoluble residues has shown only minor differences between the Tampa and Hawthorn limestones in their content of clay and sand. The Suwannee limestone, however, contains much less insoluble material, usually about 5 percent or less. Preliminary screening of sand-size residues has shown small but probably significant differences between the 3 formations.

The Tampa limestone is slightly phosphatic (less than 5 percent P_2O_5 in most samples). In a few places it has visible phosphate, and beds of at least one outcrop contain minor amounts of aluminum phosphate which may have formed in lower Miocene time since the beds are overlain by unleached Tampa limestone. The clays of the Tampa limestone analyzed so far are all of the illite group.

A comparison of semi-quantitative spectrographic analyses of 11 samples of Tampa limestone and 8 samples of Hawthorn limestone shows that the most notable difference between the two formations is the higher proportion of K in the Tampa and higher amount of Mg in the Hawthorn formation. This variation is probably a reflection of a difference in clay mineralogy of the two formations, perhaps illite versus montmorillonite.

Table 7.--Typical spectrographic analyses of Tampa and Hawthorn limestones

XO.%	X.%	0.X%	0.0X%	0.00X%
		Tampa limestone		
Ca	Si Al K Mg	Fe P	Sr Na Cr Mn Ni Ti	Pb B Ba V Ga Cu Zr Mo
		Hawthorn limestone		
Ca	Mg Si	Al K Fe P Na	Sr Cu Cr Ti Mn Ni	B Ba V Mo Pb Sn

The widespread occurrence of chert, chiefly on top of the weathered surface of Suwannee and Tampa limestones in the northern part of the area may be of value in interpreting the geologic history of the region. If the chert represents a post-Tampa, pre-Hawthorn erosion and weathering surface as postulated, it will be a useful marker zone. The chert is associated with aluminum phosphate at many places around the edge of the phosphate district.

Conclusions: stratigraphic relations and structure.--The Hawthorn formation in west-central Florida has been tentatively subdivided into 3 members: a lower medium-grained clayey sand, a middle coarsely phosphatic limestone, and an upper finely phosphatic dolomitic limestone. The sand member, however, may be a shoreward facies of one or both of the limestone members. Most of the phosphate mines of Hillsborough and Polk Counties lie on the coarsely phosphatic limestone member of the Hawthorn formation.

The Hawthorn formation has previously been regarded as conformable upon the Tampa limestone, but evidence available at present suggests that in Pasco and possibly northern Hillsborough and Polk Counties clayey and sandy beds believed to be basal Hawthorn (Mhs in Fig. 40) lie unconformably upon the Tampa. Southward the two formations may be conformable.

Unconsolidated phosphatic beds, probably of middle Miocene age in part (previously called Bone Valley formation) lie in some places upon rocks other than the Hawthorn formation. At the Tenoroc mine 4 miles northeast of Lakeland slightly phosphatic Tampa limestone is the bedrock.

The distribution of formations in northern Polk and eastern Pasco and Hillsborough Counties indicates a north-northwest trending

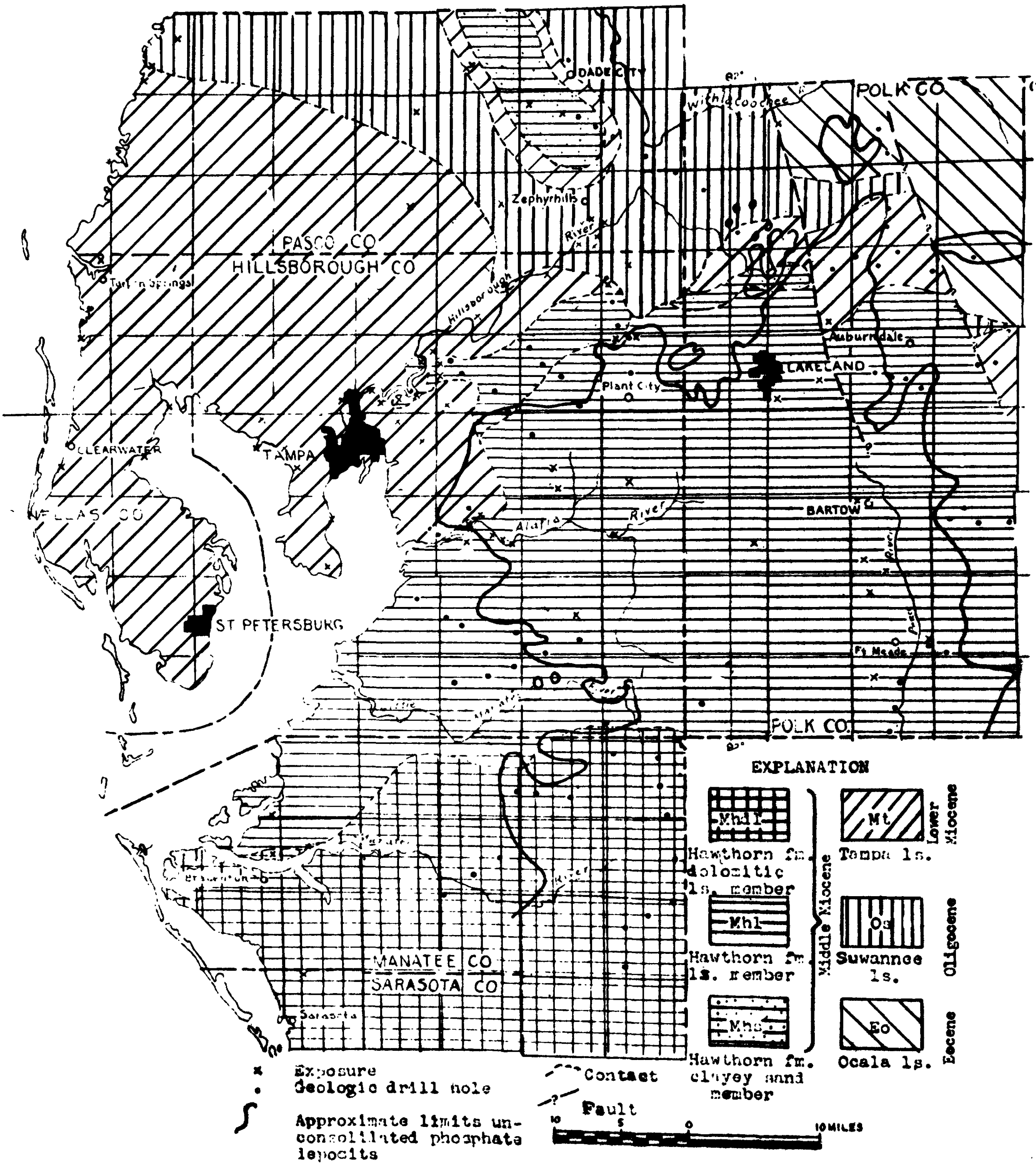


FIGURE 40.--PRELIMINARY GEOLOGIC SKETCH MAP OF PART OF WEST-CENTRAL FLORIDA POST-MIDDLE MIOCENE ROCKS REMOVED

system of gentle folds and faults of relatively small displacement. For example, in northern Polk County Eocene rocks are at the surface adjacent to Oligocene rocks, indicating a vertical displacement of at least 100 feet. The Lakeland ridge to the south may be an extension of this system. To the north faulting is suspected in the eastern Pasco County highlands. Apparently the displacements do not affect post-Hawthorn beds, but they have probably exposed different beds of limestone in the same areas to weathering, with a resulting variation in residua.

<u>The north edge of the land-pebble phosphate district</u>, by K. B. Ketner

The following three major types of unconsolidated sediments immediately to the north of the land-pebble phosphate district were studied in the field (fig. 38) and an attempt is being made to relate these to the Bone Valley formation of the land-pebble district.

1. Thick beds of coarse red clayey sands customarily termed "Citronelle formation" on the northeast and east edge of the land-pebble district and "Hawthorn formation" on the northwest edge.

2. Hardrock phosphates and related beds customarily termed the "Alachua formation."

3. Unnamed sands and clays residual from impure limestones.

Cores of unconsolidated sediments from 36 holes drilled in radial, northward trending lines across the northern edge of the land-pebble district were described and sampled and most exposures between the northern edge of the land-pebble district and the southern tip of the hardrock phosphate belt were described. Unconsolidated sediments exposed in a hardrock phosphate pit and parts of a limestone quarry were mapped on a large scale for the purpose of illustrating structural and stratigraphic relations.

The East edge of the land-pebble phosphate district, by L. J. McGreevy

The so-called Citronelle formation along the eastern edge of the land-pebble phosphate district is predominantly a reddish mottled, somewhat crossbedded, clayey sand. Field work during June and July was confined chiefly to a study of available exposures of this formation in the higher ridge area of central Polk County, in an attempt to determine its stratigraphic relationship to the Bone Valley formation immediately to the west.

During July and August approximately 26 holes were drilled along 4 lines extending eastward from the lower lying phosphate mining district to the higher ridge area. Preliminary observations indicate that the Citronelle formation, which is restricted to ridge and knoll tops, possibly represents an extensive bar deposit and is probably younger in age than the Bone Valley formation.

Stratigraphic studies of the post-Miocene sediments of the west edge of the B ne Valley formation, by R. G. Petersen

The area under investigation is shown in Fig. 38 and extends westward from the westernmost phosphate mine (Sydney Mine) of the land-pebble district to Tampa Bay on the Gulf of Mexico.

Field work began in April, 1953. A truck-mounted power auger drilled 70 holes in this area. Outcrops in the area were examined and mapped and surface sand samples were collected for mechanical analysis.

The following are interpretations based on incomplete field work:

1. An apparently continuous clay bed can be traced from the westernmost phosphate mine to Tampa Bay.
2. Stratigraphic relations can be shown between this clay bed and a Pleistocene shell bed near Tampa Bay.

3. The bed-rock rises under the so-called 80-and the 100-foot marine terraces.

4. The phosphate-containing beds are continuous over these bed-rock highs.

5. Mechanical analyses of surface sand show changes in sorting and in median diameter at the so-called 10- and 30-foot terraces but not at the 80- and 100-foot levels.

Plans for future work include additional drilling, mapping, and analytical work, leading to preparation of a manuscript for publication as a U.S.G.S. Bulletin.

Mineralogic and petrologic studies
by Z. S. Altschuler

Little data are available concerning the relations of the Bone Valley formation to the underlying bedrock. By plotting measured stratigraphic sections in several profiles across the Land Pebble District, Florida, it has been determined that the formation conforms to the regional highs and lows of the topography. This proves that post-Bone Valley structural changes of a regional nature have occurred in central Florida and that the Bone Valley formation is not flat-lying over the region.

Mechanical analyses and heavy mineral studies of uppermost Hawthorn and immediately superincumbent Bone Valley formations reveal differences in size distribution and heavy mineral suite which indicate that the Bone Valley was not derived from the Hawthorn by mere leaching of lime. In several localities thus far studied the quartz fraction of the Hawthorn formation is coarser and less rounded than the quartz in the superjacent Bone Valley. The following differences in heavy mineral assemblage were noted in a section at Achan: (1) the percentage of zircon in the Bone Valley is double that in the Hawthorn and (2) garnet and tourmaline are much more prominent in the Hawthorn formation than in the Bone Valley formation. The conjunction of all of these changes seems best explained by the hypothesis that the Bone Valley material has been redeposited.

Spectrographic analyses have been made of apatite, montmorillonite, kaolinite, and pseudowavellite for study of their trace-element content. It was found that V, Fe, Mg, Ti, and Cu are more concentrated in the clays than in the phosphate minerals; Sr, Y, Mn, and Sc are most concentrated in apatite; Ba is relatively concentrated in pseudowavellite; and more Co occurs in montmorillonite than in the phosphate minerals. Comparisons between leached and fresh apatite pebbles showed that Y, Mn, and Sc are relatively enriched in the former. In the latter, Cu is relatively enriched. In most of the above the differences in concentration are less than tenfold; and more analyses are needed before any distribution pattern can be established.

A small-scale contour map was compiled for the purpose of studying the relation of topography to isograde and isopach data of the leached zone. In several small areas patches of thick leached zone occur in areas of greatest topographic slope. However, most of the leached zone could not be correlated as readily with slope or relief and the contour data available are too sparse for analyses of this type over the Land Pebble Field.

Generally the sedimentary apatite of the Bone Valley and Phosphoria formations is completely anhedral in morphology. Specimens that have originated by secondary replacement of clays have been found to be euhedral. A specimen of replacement origin exhibited well defined rod-like prismatic form. In addition, very small euhedral skeletal crystals of apatite have been found in the finest fractions of some of the clays in the Bone Valley formation.

The detection and identification of the skeletal crystals was made by electron microscope and diffraction studies.

Although it has been established that carbonate-fluorapatite is structurally different from normal fluorapatite and can be readily distinguished therefrom, the nature of the relation between F and CO_2 content and the change in lattice dimensions has not been worked out. This is mainly the result of the lack of good materials with appreciably different chemical analyses. Most well-crystallized carbonate-fluorapatite has 2 to 3 percent of CO_2. The carbonate-fluorapatite from Richtersveld, South Africa, has roughly 5 percent of CO_2 and thus affords an opportunity for comparing changes in lattice dimensions with chemical composition. This work is now in progress.

Preliminary experiments are under way for determining the valence state of uranium in selected specimens of igneous and sedimentary apatite. The standard cupferron extraction method is being used; preliminary runs, however, are being made on spiked samples because of the very low contents of uranium present.

THORIUM AND MONAZITE DEPOSITS

Southeastern Coastal Plain
by Lincoln Dryden

Field work in the southeastern coastal plain was completed in May 1953. Work during the summer consisted of (1) preparation of a report on "Monazite in Atlantic shoreline features" and (2) laboratory work and report writing on monazite in samples of the Tuscaloosa (Cretaceous age) and other formation of the southern coastal plain.

(1) The report on "Monazite in Atlantic shoreline features" was essentially completed in July, but submittal was delayed pending receipt of information from company sources in October. The report discusses monazite in areas that obviously or presumably were once shoreline features such as beaches, spits, bars, or dunes. In addition to Trail Ridge and an area at Jacksonville, Fla., now being worked, and three or four other areas that are reported to be in various stages of development, the report describes several other deposits that probably are not of commercial grade.

(2) Approximately 450 samples from the Tuscaloosa and other formations of the coastal plain from North Carolina to Alabama were examined in the laboratory with a Geiger counter. Heavy mineral suites were separated, weighed, and tested for radioactivity which is apparently caused by the monazite content. It was noted that in Atlantic shoreline features monazite normally composes less than one percent of the heavy minerals, but that in the Tuscaloosa and older formations it averages from 2 to 3 percent and at two localities reaches more than 10 percent. Of the 450 samples, 26 contained 1/2 to one pound of monazite per cubic

yard, three contained one to 1-1/2 pounds, five contained 1-1/2 to 2 pounds, and one contained 2-1/2 pounds. Location of the samples, the percentage of monazite in the heavy-mineral suites, and the number of pounds of monazite per cubic yard were plotted on parts of the state maps of North Carolina, South Carolina, Georgia, and Alabama. Inasmuch as sampling was carried out by rapid reconnaissance methods at widely separated localities it is impossible to estimate reserves of any given tenor.

A report on sampling and laboratory methods and on the occurrence of monazite in the coastal plain formations will be transmitted before the end of the fiscal year.

Southeastern monazite
by W. C. Overstreet

During the past six months work of the project consisted principally of report preparation, though a small amount of field work was done in the Knob Creek area, Cleveland County, N. C., the Yadkin River-Dan River district, N. C.-Va., and the Oconee River district, Ga. Office compilation was completed of maps showing monazite placers in the drainage basins of the following streams: the Savannah, Saluda, Enoree, Tyger, and Pacolet rivers, and southern tributaries of the Broad River in South Carolina and the Catawba River in North Carolina. A similar map covering the northern tributaries of the Broad River, and a planimetric map on a scale of 1:20,000 of placers in the Savannah River-Catawba River district, S.C.-N.C., are now being drafted.

Reports on placers drilled during the winter of 1952-53 as part of the joint Survey-Bureau of Mines program were finished, thus completing the Survey's part of that project. The text and illustrations for the report on the Knob Creek area were begun and it is expected that the report will be transmitted before June 30, 1954. Plans for the final report on the project have been modified to permit completion by the end of the fiscal year. The following studies contributing to the final report were completed: (1) a discussion of limits of accuracy in field and office procedures; (2) a list of accepted spellings of stream names; (3) variations of relief in the monazite belt; (4) niobium determinations on samples of placer rutile and ilmenite; and (5) carbon 14 age determinations of wood from placer deposits.

Wet Mountains, Colorado

by Q. D. Singewald and R. A. Christman

Field work was done within a 63-square mile "special topographic area" on the western flanks of the Wet Mountains. Detailed mapping at 1:6,000 was begun during the 1952 season, when five square miles were completed. During the 1953 season 17 square miles were mapped in detail and an additional 2½ square miles were mapped in reconnaissance (see fig. 41).

The rocks are pre-Cambrian gneisses and granites, exhibiting complex relationships, crosscut by basic to syenitic dikes and by veins containing thorium (as thorite), barite, carbonate minerals, iron oxides and minor sulfides and rare earths. A final set of field units was formulated to replace the experimental, more detailed units used in 1952. The major rock types are 1) microcline granite, 2) "Pikes Peak" granite, 3) migmatite, 4) hornblende gneiss, 5) quartz-plagioclase-biotite gneiss, and 6) undifferentiated gneisses (metasediments?). The map units consist

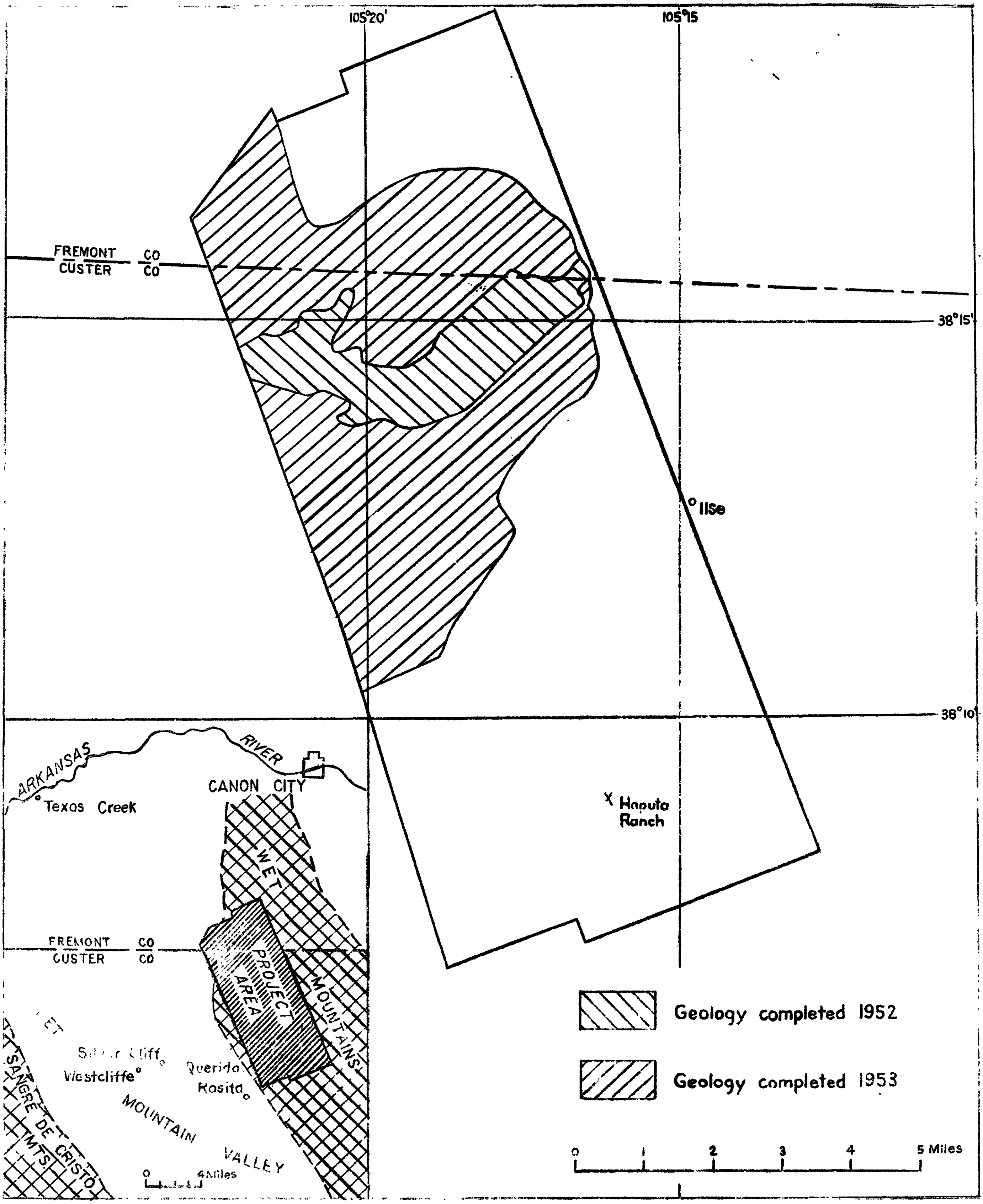


FIGURE 41.--MAP OF WET MOUNTAIN PROJECT AREA, FREMONT AND CUSTER COUNTIES, COLORADO

of these types individually or, more commonly, in various interlayered combinations. The quartz-plagioclase-biotite gneiss was not previously recognized, but was identified by study of a large number of powdered rock samples under the microscope. The studies showed the amount of introduced potash feldspar to be smaller than originally supposed.

Continuing systematic search for radioactive veins and shear zones resulted in discovery of several moderate to strongly radioactive localities in the northern part of the mapped area; many weakly radioactive localities were also discovered. A map showing the location and the approximate amount of observed radioactivity at all the localities is in preparation. Much of the radioactivity work consisted of extending previously mapped veins and in mapping properties known from earlier reconnaissance and from taxpayer examinations. Many localities examined earlier with Geiger counters were re-visited and scintillation counter readings taken in order to obtain uniform data for the entire mapped area.

The outline of a slightly radioactive monzonite stock of possible Tertiary age, along Grape Creek, was determined by reconnaissance; it appears to be about 2 1/2 square miles in area. A 50-pound sample was submitted for age determination by the zircon method.

Field work was recessed November 6. A report summarizing the work of the past two field seasons, and a geologic map, will be prepared during the next six months.

Powderhorn district, Colorado

by J. C. Olson and S. R. Wallace

The Little Johnny thorium deposit, in sec. 15, T. 47 N., R. 2 W. was mapped at a scale of 1:1,200. Thorite, the principal thorium-bearing mineral in the deposit, occurs in a vein exposed discontinuously over a length of more than 3,000 feet and ranging in thickness from a few inches to about 5 feet. Analyses of 11 samples range from 0.08 to 1.12 percent ThO_2; one sample contains as much as 4.4 percent.

Field work was terminated August 6, 1953. A report on the district is in preparation.

RECONNAISSANCE FOR URANIUM IN THE UNITED STATES

Northeast district

by F. A. McKeown and Harry Klemic

Rare-earth-bearing apatite, Mineville, N. Y.

Analyses of apatite separated from magnetite ore from the Old Bed and the ore body at the Smith Mine, Mineville, N. Y. show higher rare-earth, thorium, and uranium contents than previously reported (TEI-317). The samples contain from 4.28 percent to 32.4 percent Re_2O_3; 0.01 percent to 0.38 percent ThO_2; and 0.009 percent to 0.11 percent U. All laboratory data indicate that the mineral containing these elements is fluorapatite. The samples were taken from the Smith Mine (inactive) and six levels in the Old Bed, which is currently being mined by Republic Steel Corporation. No change in mineralogy or distribution of elements appears in different parts of the mine.

Uranium occurrences in Carbon County, Pa.

Uraniferous sandstone in the upper part of the Catskill formation of Devonian age was discovered at two localities in Carbon County, Pa. during July. Near Butcher Hollow, about four miles north of Mauch Chunk, uraniferous rock is present along 30 feet of outcrop on the west side of the Lehigh River and in talus on the opposite side of the river about 500 feet away. The average uranium content of four samples representing about 2 feet of a 6-foot interval of rock is 0.016 percent. A selected specimen of radioactive rock from the talus on the east side of the river contains 0.055 percent U.

At the other occurrence, about 0.4 miles south of Penn Haven Junction, uraniferous rock occurs along 300 feet of outcrop on the west side of the Lehigh River and crops out on the east side of the river about 500 feet away. Assays of 13 samples from the western outcrop weighted against the length of the sample average 0.053 percent U. A selected sample of radioactive rock from the eastern outcrop contains 0.30 percent uranium. Kasolite and uranophane occur sparingly at this locality.

Uranium occurrences at Clinton, N. J.

Approximately 0.5 square mile at Clinton, Hunterdon County, N. J., including all known occurrences of radioactive material, has been mapped at a scale of 1:1,200. The area is underlain by folded and faulted Kittatinny limestone of Cambro-Ordovician age. The uranium deposition probably was controlled by faults. Uranium occurs in one fault zone about 15 feet wide and more than 400 feet long and in several small faults that generally have a displacement of less than 10 inches. The faults strike west and dip nearly vertical or steeply south. The greatest concentration of uranium in these fault zones is in clayey gouge or in glassy coatings on fractures. X-ray powder patterns of four selected samples of the most radioactive material from several places in the fault zones show apatite, and dolomite or carbonate material in every sample; montmorillonite is present in one. Uranium is also disseminated in an unknown form in two 4-inch layers of black siliceous dolomite near a fault and in several zones of residual soil. Samples taken during 1952 (TEI-317) and outcrop radiometry indicate the uranium occurrences at Clinton are too low grade to be of current economic interest.

Uranium in Triassic rocks, Bucks County, Pa. and Hunterdon County, N. J.

Ten occurrences of uraniferous argillite in the Lockatong formation and 3 occurrences of uraniferous sandstone in the Stockton formation, Triassic age, were discovered in Bucks County, Pa., and Hunterdon County, N. J., during July and August. The argillite contains as much as 0.05 percent U, though it more commonly contains from 0.01 to 0.02 percent U. An area about 600 by 300 feet at Delaware Quarry, 2 miles north of Pt. Pleasant, Bucks County, Pa., was mapped at a scale of 1:360 because the most uraniferous and best exposed argillite crops out there. This work indicated that the uranium may not be coextensive with a bed for more than several hundred feet; the uraniferous zones, however, do not transect bedding. The uraniferous sandstone occurrences are small, commonly less than 50 feet long and 1 to 2 feet thick. The largest is discontinuously radioactive along a strike length of about 250 feet. The sandstone is medium- to fine-grained, arkosic and commonly has clay pebbles mixed with it, particularly where the uranium content is greatest. Autunite (?) and torbernite (?) were found in one sample. Assays of samples are incomplete; however, they are estimated to range from about 0.02 percent to 0.05 percent U. None of the known uranium occurrences, either sandstone or argillite, is now economically significant.

Phillips pyrite mine, Putnam County, N. Y.

At the Phillips pyrite mine, Putnam County, N. Y., uraninite is associated with magnetite, hornblende gneiss, and possibly a sulfide-bearing shear zone in diorite. An area about 1,000 by 450 feet in the vicinity of the mine has been mapped at a scale of 1:1,200. Though no analogous deposits are known to the writers, this occurrence may be significant. If the uranium is coextensive with the magnetite-bearing rock (actually lean magnetite ore), there may be a large tonnage of uranium; the magnetite rock is similar to the type of magnetite ore commonly found in gneiss of the Adirondack Mountains and the Highlands of New Jersey and New York.

Miscellaneous examinations

Thirty-five iron, lead-zinc, copper, and manganese deposits were examined; none were significantly radioactive. Extremely high gamma-ray anomalies were found by the Schlumberger well logging company at the Oakford gas field, Jeannette, Westmoreland County, Pa. The anomalies, probably caused by radon, are at the Big Injun Sand (Pocono formation), Murrysville sand (Pocono or Catskill formation), and the 100 Foot Sand (Catskill formation). A gas well in Shenango County, N. Y., is reported to have a very high gamma-ray anomaly at a shale in the Oneida conglomerate of Silurian age. The Marcellus and Utica shale in this well are also radioactive, but not exceptionally so for black shales.

Southeast district
by H. S. Johnson

Investigations were made for radioactivity in (1) copper-bearing veins in North Carolina and Virginia; (2) disseminated copper deposits in Triassic sedimentary rocks and pre-Cambrian volcanic rocks in Virginia; (3) pyrrhotite ores in western North Caroline; (4) barite and fluorite veins in Tennessee, North Carolina, and South Carolina; and (5) vermiculite deposits in South Carolina. No radioactive materials of potential economic significance were found during these investigations.

In October the project was recessed indefinitely. A final report on "Reconnaissance for uranium and thorium in the southeastern states, 1953" will be transmitted.

Results of a year's reconnaissance in the Southeast indicate:

1. The deposits most likely to produce significant quantities of fissionable materials are Florida phosphate, Chattanooga shale, Piedmont monazite, and Coastal Plain monazite.

2. Probably the most favorable ground for further reconnaissance is in Devonian through Pennsylvanian rocks of the Valley and Ridge and Appalachian Plateau provinces and in the western Kentucky coal field.

3. The gold, copper, and tungsten-bearing quartz veins of the Piedmont province are at best only moderately favorable for uranium deposits.

4. Granites near Elberton and Stone Mountain, Georgia, and elsewhere in the Southeast contain very small amounts of radioactive materials.

South-Central district
by J. W. Hill and E. P. Beroni

Reconnaissance was continued in Missouri, Arkansas, Louisiana, Texas, and Oklahoma, comprising the South-Central district. Thirteen radioactive deposits not previously reported (see table 8) were found.

Table 8.—Radioactive materials, south-central district

Area	Location	Type material	ANALYSES Uranium (percent)	Equivalent uranium (percent)	Uranium ppm	Ash (percent)	Remarks
OKLAHOMA							
NE Okla.	Picher Field Ottawa Co.	Asphaltic tar	0.015* 0.072*	0.004* 0.014*	3.8* 1.6*	2.558 .228	Tar seeps from Pennsylvanian Cherokee fm., seeping into Eagle-Picher zinc mines - limited quantity.
NE Okla.	Craig Co.	Coal	-	0.005 0.02*	-	-	Coal bed 1/2 ft thick in Pennsylvanian Cherokee fm., 6 mi. N. of Vinita. Analysis in progress.
NE Okla.	Pawnee Co.	Carbonized wood	0.30	0.25	-	-	Selected fragments of cupriferous carbonized wood from secondary copper deposit in basal Permian ss. Otoe Mines, Inc. - limited quantity.
SE Okla.	Ouachita Mts. McCurtain Co.	Valliant deposit asphaltic ss.	0.010*	0.001	2.8*	2.86	Analysis of oil extract (8.18%). Sandstone of Paluxy fm., Cretaceous age; radioactivity may be related to production of radioactive fluids from same formation in Talco oil field, 60 mi. south.
S. Okla.	Arbuckle Mts.	Phosphatic nodules	0.010	0.009	-	-	Phos. nodules profusely scattered in Woodford chert of Mississippian-Devonian age. Exposed in outcrops.
SW Okla.	Limestone Hills area, Kiowa Co.	Asphaltic ss.	0.019*	0.002	0.496*	.261	Black asphaltic ss. in basal Permian fm. near surface exposures of uraniferous asphaltic pellets. Oil extract is 5.71 percent of sample.
SW Okla.	Limestone Hills area, Kiowa Co.	Asphaltic pellets	20.0	-	-	-	Dense black pellets from drill samples of basal Permian fms., (-1000 ft or deeper) Royal Petrol. Co.-Krieger No. 3 well. Uraninite in pellet identified by X-ray.
SW Okla.	Limestone Hills area, Kiowa Co.	Radio-barite	0.001	0.077	-	-	Tuffaceous spring deposit overlying basal Permian fms., may be related to nearby uraniferous asphaltic pellets.
SW Okla.	South Carnegie oil field Caddo Co.	Oil	0.002*	-	0.244*	1.22	Oil from shallow Permian fm. that contains asphaltic pellets in nearby surface exposures.
SW Okla.	Cement oil field Caddo. Co.	Oil	0.0009*	-	0.248*	2.76	Spectrographic analysis shows 20 ± percent V in ash. Oil from Pennsylvanian Marchand sand.

Table 8.—Radioactive materials, south-central district—Continued

Area	Location	Type material	ANALYSES Uranium (percent)	Equivalent uranium (percent)	Uranium ppm	Ash (percent)	Remarks
OKLAHOMA							
SE Okla.	McAlester Basin Coal Co.	Coal	-	0.005 0.01*	-	-	Coal of Pennsylvanian McAlester fm., 2 to 5 ft thick. Abandoned strip pit sampled. Analyses in progress.
E. Okla.	Sequoyah Co.	Spring deposit	0.001	0.013	-	-	Gray silty limonitic clay, bordering mineral water spring; water contains 0.004 ppm uranium.
TEXAS							
NW Texas	Midland Basin, Lubbock Co.	Caliche?	0.016	0.017	-	-	Small knob of dense, white, crystalline caliche of Tertiary age (?) exposed in stream valley. More radioactive on upstream position.
NW Texas	Midland Basin, Nolan Co.	Carbonaceous siltstone	0.63 0.027	0.32 0.018	-	-	Gray micaceous siltstone, 5 ft thick of Triassic (?) age. High value (0.63% U) from selected carbonaceous plant fragments. Reconnaissance in progress.
Central Texas	Llano Uplift, Llano Co.	Uranium-zircon minerals	-	0.30	-	-	Hydrothermally altered granite. Analysis and reconnaissance in progress
Central Texas	Llano Uplift, Burnet Co.	Asphaltic coquina	0.0045*	<0.001	1.2*	2.63	Asphalt-impregnated coquina of Cretaceous Glen Rose fm. Oil extract = 3.4%.
SW Texas	Pecos Co.	Meta-tyuyamunite	0.063	0.029	-	-	Encrustation on gray siltstone; reconnaissance in progress.
SE Texas	Waller Co.	Fossil bones	0.068	0.060	-	-	Bones exposed as small component of (Middle Miocene) Fleming fm. Outcrop extends from Rio Grande to Sabine uplift.
KANSAS							
SE Kans.	Crawford Co.	Coal	-	0.005 0.015*	-	-	Two ft thick coal in (Pennsylvanian) Cherokee fm. abandoned strip pit 12 mi. south of Fort Scott, Kansas. Analyses in progress.

* In ash

North-Central district

by R. C. Vickers

Field work included (1) geologic mapping of the autunite occurrence in Lawrence County, South Dakota; (2) geologic mapping of an occurrence of secondary uranium minerals at the Graphite quarry, Baraga County, Michigan; (3) geologic mapping and sampling of the monazite-bearing Goodrich quartzite in the Palmer area, Marquette County, Michigan; (4) Reconnaissance of lead, zinc, silver, and copper occurrences in northern Michigan; and (5) reconnaissance of the nepheline-syenite complex near Wausau, Marathon County, Wisconsin.

Bald Mountain mining district, South Dakota

Geologic mapping of the Annie Creek autunite occurrence showed that part of the uranium is concentrated along north- to northeastward-trending fractures in siltstone and in a northeastward-trending dike in rhyolite porphyry below the siltstone. Channel samples in the underground workings indicate an average grade of about 0.03 percent U. No material of ore grade was observed. The siltstone does not crop out in the vicinity, and sample information is available only from the small underground workings and several old prospect pits. Exploration of the occurrence is warranted and under consideration by the owners of the property.

During a reconnaissance of the workings and prospects along the strike of the fracture system at the autunite occurrence, material containing 0.1 percent U and 0.19 percent eU was found about 1,000 feet to the northeast. The radioactivity was associated with narrow altered siltstone stringers. A sample of silicified siltstone from the Maria and Mary claim, about 500 feet to the northeast contained 0.041 percent eU and 0.007 percent U.

Abnormal radioactivity also was detected at three localities in the vicinity of Bald Mountain. An altered porphyry from the Decorah mine contained 0.025 percent eU and 0.008 percent U. Samples of an altered diatreme contained as much as 0.045 percent eU and 0.006 percent U. A sample of siltstone near a porphyry contact on the Mikado claim contained an estimated 0.08 percent eU. Manganese-stained fractures along a sheer zone contained 0.026 percent eU and 0.017 percent U.

Uranium mineralization in the district is now believed to be more widely distributed than was previously suspected. The occurrences may provide valuable information concerning the origin of the uranium in the sediments surrounding the Black Hills.

Baraga County, Michigan

Yellow-green uranium minerals are associated with an altered lamprophyre dike that cuts graphitic black slate at the Graphite quarry in Baraga County, Michigan. Selected samples contain more than 0.1 percent uranium. Radioactivity appears to increase with depth. Although minable tonnages of material of ore grade were not observed, higher-grade material may exist at depth or along the dike, which is exposed only in a small abandoned quarry.

Monazite-bearing Goodrich quartzite, Palmer area Marquette County, Michigan

Geologic mapping, sampling, and gamma-ray logging of diamond-drill holes in the Palmer Area shows that the monazite is concentrated in beds of pebble conglomerate up to one foot thick, containing as much as 5 percent monazite. Gamma-ray logging of three drill holes which penetrate the Goodrich showed that the most radioactive part of the formation is about 400 feet stratigraphically above the base. Channel samples were taken of all known outcrops of the Goodrich formation in the area, but these outcrops are practically limited to the lower 300 feet of the formation. It is estimated that the average monazite content of these samples is about 0.4 percent. The grade indicated by the gamma-ray well logging is unknown at present, but an attempt is being made to correlate the logs in terms of actual monazite content.

Lead, zinc, silver, and copper occurrences, northern Michigan

Although copper and zinc minerals are associated with the occurrences of pitchblende at Huron River, Baraga County, and at the Sherwood mine in the Iron River district, Iron County, Michigan, no abnormal radioactivity was detected associated with several lead, zinc, copper, and silver prospects examined in Marquette and Gogebic Counties, Michigan.

Nepheline-syenite complex, Marathon County, Wisconsin

In the Wausau area, T. 29 N., R. 6 E., Marathon County, Wisc., an occurrence of thorogummite was discovered beneath two feet of soil. The anomaly is believed to be caused by near-surface concentration by weathering of a thorium-rich rare-earth pegmatite. The weathered material in the bottom of a shallow hole contains an estimated 10 percent thorium. The discovery was in the center of a radioactivity anomaly which was found in May 1953 (see TEI-330, p. 206). Additional reconnaissance with a scintillation detector increased the known dimensions of the anomaly to a length of 800 feet and a width of 2 to 10 feet. There are no outcrops in the area, and the size and grade of the occurrence are unknown.

During this report period, a second anomaly, about 100 feet long and 70 feet wide on the surface, was found three-fourths mile to the northeast. There are no outcrops in the area, but radioactive float consisting of amphibole (?) and perthite containing thorium-rich hematite fracture-coatings was found along a nearby fence row. The material is estimated to contain several percent thorium in addition to zircon and possibly rare earths.

Colorado-Wyoming district

by R. U. King

Three districts in southeastern Wyoming (fig. 42) and five districts in central Colorado (fig. 43) were examined for radioactive materials. With minor exceptions, the results of this reconnaissance were negative and indicate that the following districts offer little promise of significant deposits of radioactive materials: (1) Lusk and (2) Guernsey districts in Niobrara, Goshen, and Platte Counties, Wyo.; (3) Encampment district, Carbon Co., Wyo.; (4) Rollinsville-Plainview district, Boulder and Jefferson Counties, Colo.; (5) Champaign mine and vicinity, Park Co., Colo.; (6) Rhyolite Mountain area, Cripple Creek district, Teller Co., Colo.; (7) Breckenridge district, Summit Co., Colo.; and (8) Argentine district, Summit and Clear Creek Counties, Colo.

The copper-silver-iron deposits in the Lusk and Guernsey districts are commonly slightly radioactive and contain from 0.001 to

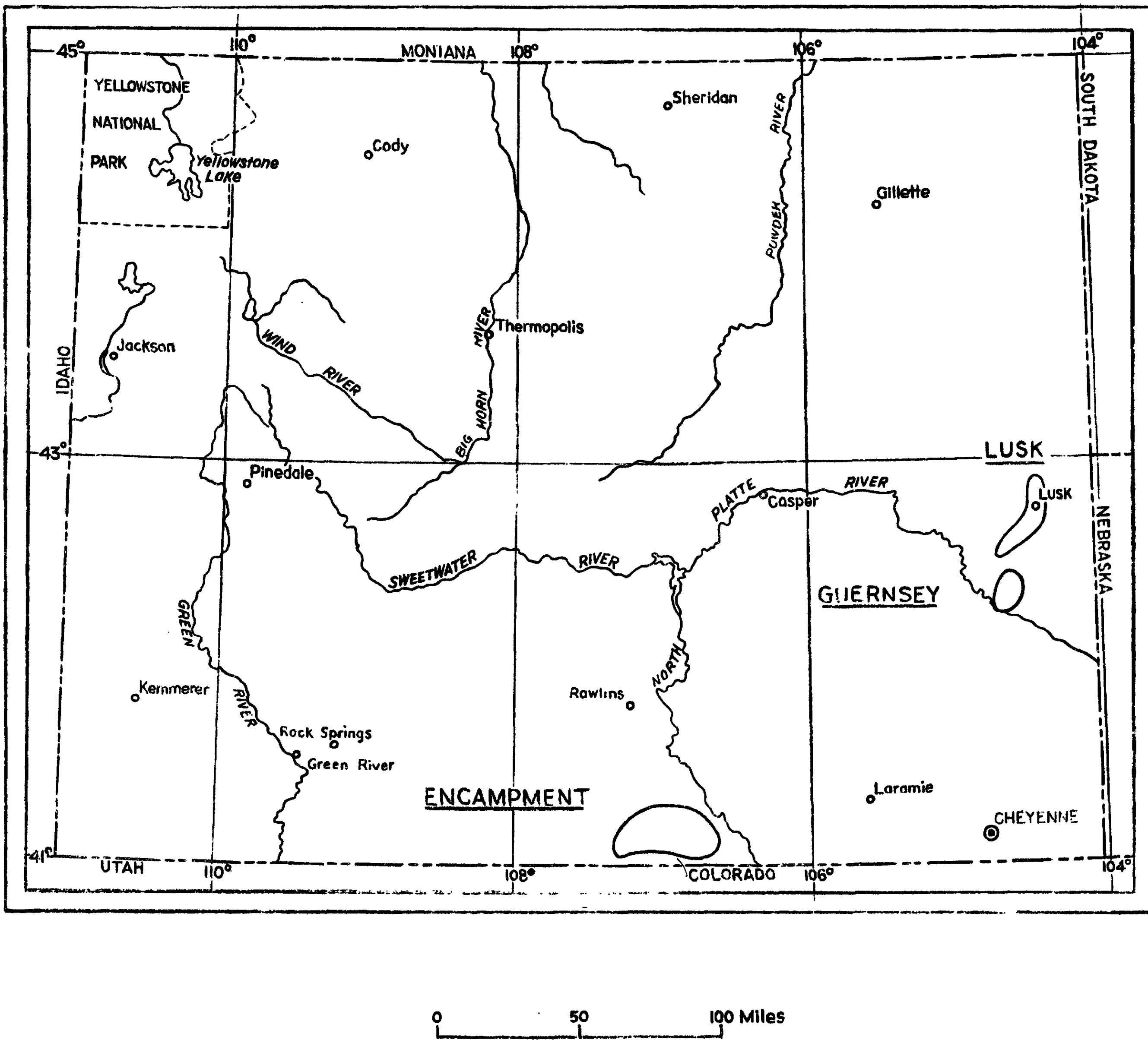


FIGURE 42.--INDEX MAP OF WYOMING SHOWING DISTRICTS EXAMINED FOR RADIOACTIVE MATERIALS

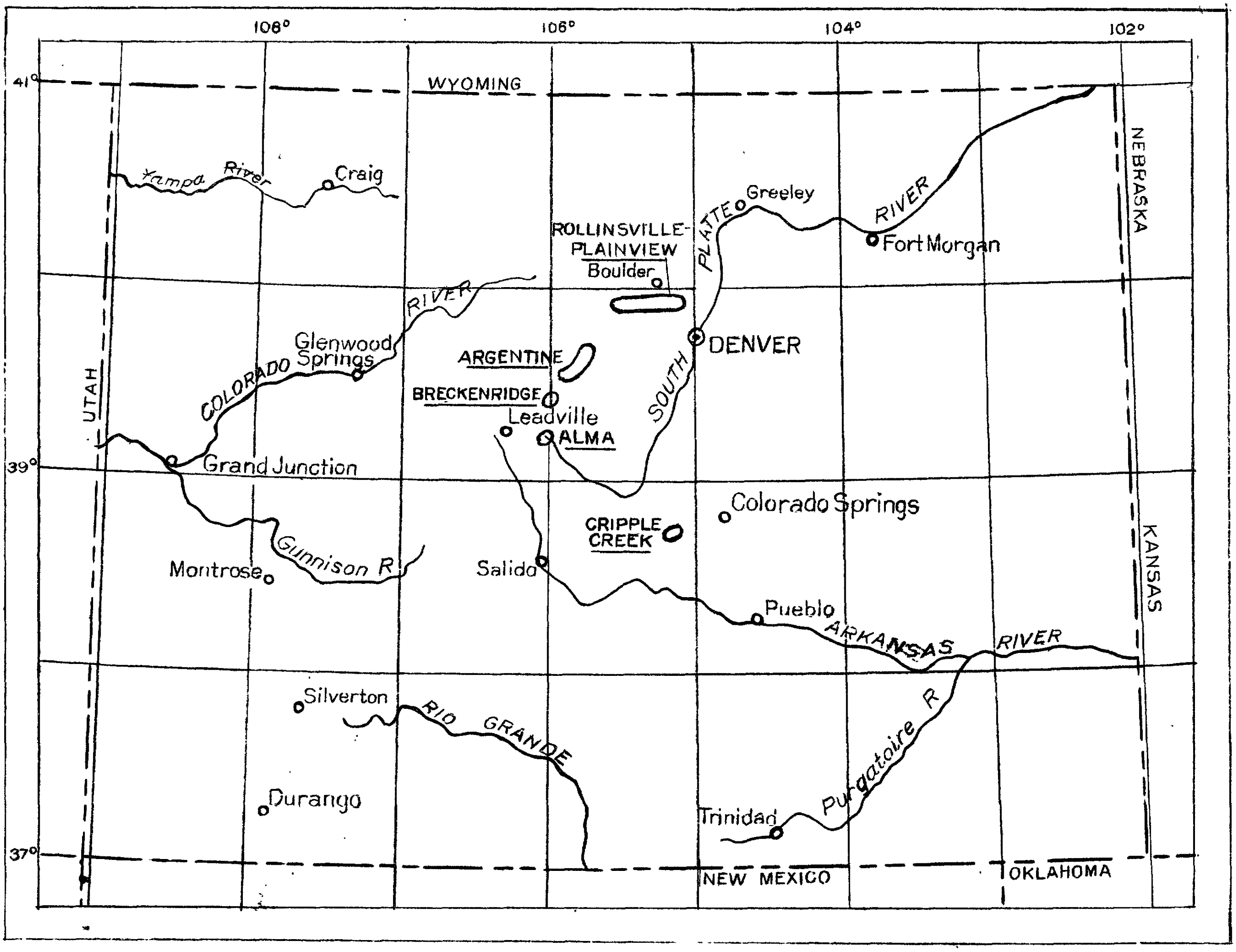


FIGURE 43.--INDEX MAP OF COLORADO SHOWING AREAS EXAMINED FOR RADIOACTIVE MATERIALS.

0.043 percent U. The uranium is associated with secondary copper minerals and limonite, and generally occurs as fracture coatings, in brecciated zones in schist of pre-Cambrian age.

The copper-gold veins of the Encampment district are with few exceptions not abnormally radioactive. Malachite-stained vein material from the dump of the Doane-Rambler mine in sec. 25, T. 14 N., R. 86 W., 14 miles southwest of the town of Encampment, Wyo. contains 0.010 percent U. A biotite-feldspar-garnet pegmatite in the eastern part of the district contains 0.12 percent eU and 0.10 percent U in the most radioactive part of the dike.

The breccia reefs and country rocks in the Rollinsville-Plainview district were found to be essentially non-radioactive.

Radon, as much as 15,000 to 20,000 micro micro curies per liter, was found in the adits of the Champaign mine in the Alma district. The main adit was sampled and mapped in detail in an attempt to discover the source of the radon, but without success. Samples of vein material and wall rocks contain from 0.011 to 0.005 percent U; mine water contains from 0.003 to 0.66 ppm U. Limonite coatings on fractures cropping out near the Champaign mine contain up to 0.008 percent U.

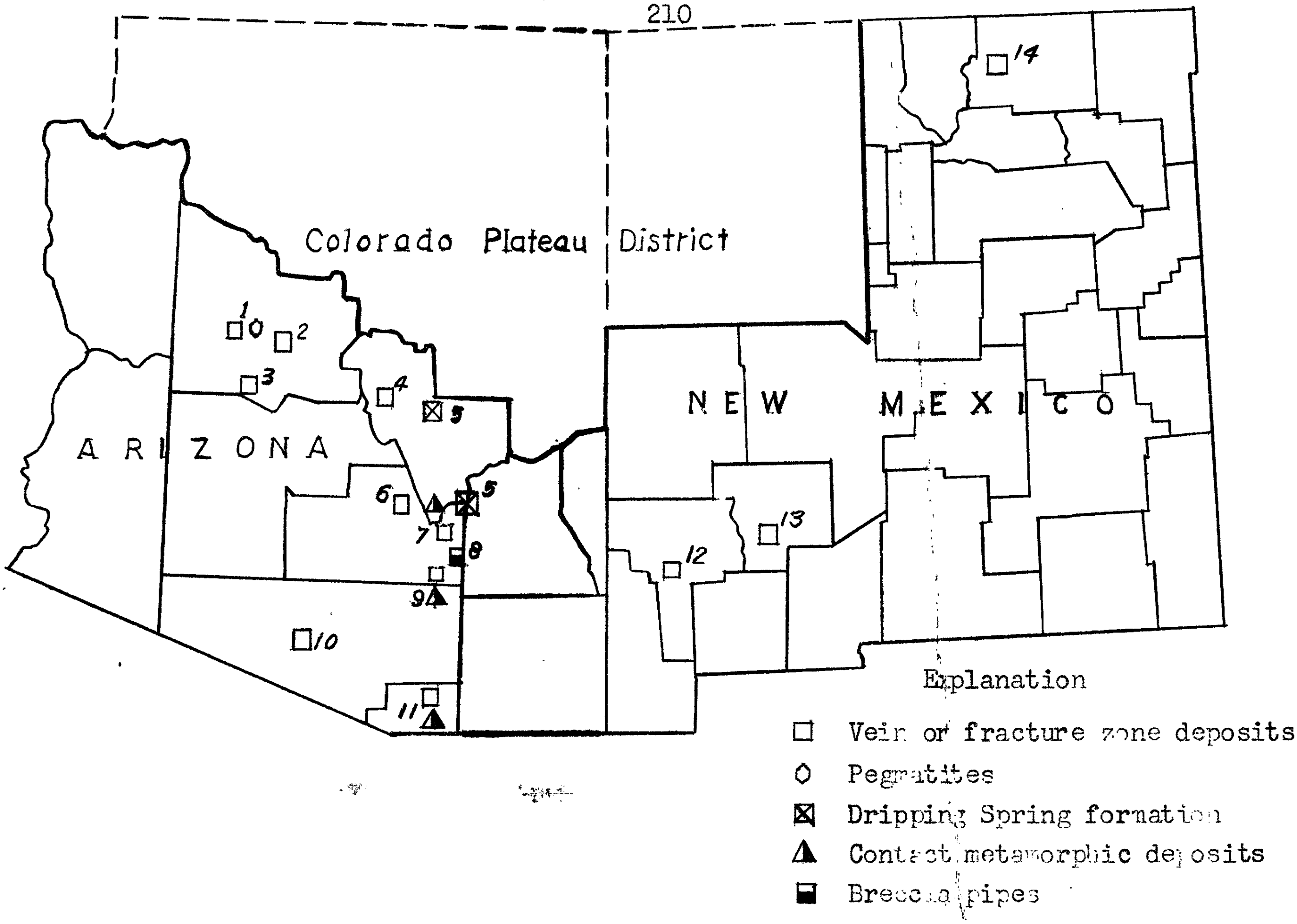
In the Cripple Creek district an area including Rhyolite Mountain and Copper Mountain was investigated to check a reported occurrence of pitchblende in a vein deposit. No uranium was found in any of the workings examined, but it was noted that the phonolite was 2 to 4 times as radioactive as the underlying pre-Cambrian granite. The radioactivity of the phonolite is estimated to be equivalent to a content of 0.003 to 0.007 percent U.

The mines of the Breckenridge district exploit gold-silver-lead-zinc vein deposits in sedimentary rocks of Carboniferous, Jurassic, and Cretaceous age, and igneous rocks of Tertiary age. In the Argentine district the country rock consists of gneiss and schist of the Idaho Springs formation intruded by Silver Plume granite and monzonite porphyry. The most commonly observed minerals of these districts are sphalerite, galena, chalcopyrite, pyrite, quartz, carbonates, and fluorite. Reconnaissance disclosed one significant anomaly on the dump of the Jumbo mine one mile northeast of Montezuma. The source of the radioactivity apparently is a yellow-brown powdery material coating altered monzonite. It is estimated that the radioactive material contains about 0.005 percent eU. This anomaly is near two other radioactive deposits found previously on the north slopes of Glacier Mountain just south of Montezuma (Dings, TEI-296).

Southwest district
by R. B. Raup

Anomalous radioactivity was detected during the past six months in the five areas described below:

1. Bunker Hill (Copper Creek) district, Pinal Co., Ariz., (fig. 44). The mines in the district contain copper and molybdenum in breccia pipes in Tertiary volcanic rocks. Although small increases in radioactivity were recorded (up to 3½ times a low background radioactivity on the 0.025 mr/hr. scale of a scintillation counter), no significant concentrations of radioactive material were found. The deposits that contain molybdenite visible in hand specimens commonly are more radioactive than those without visible molybdenite.



1. Weaver Mountains
2. Hassayampa, Turkey Creek, Tiger, Pine Grove, Walker, Big Bug, and Groom Creek districts
3. Black Rock district
4. Payson-Mazatzal Mountains area
5. Dripping Spring quartzite formation, examined in the general area of the symbols
6. Area west of Kelvin
7. Banner and Saddle Mountain districts
8. Bunker Hill (Copper Creek) district
9. Old Hat (Mammoth, Oracle, Control) district
10. Copper Squaw mine, DMEA loan application denied
11. Patagonia, Tyndall, and Wrightson districts
12. Tyrone district
13. Hillsboro and Kingston districts
14. Elizabethtown district

FIGURE 44.---INDEX MAP OF ARIZONA AND NEW MEXICO SHOWING AREAS EXAMINED FOR RADIOACTIVE MATERIALS, JUNE TO NOVEMBER 1953

2. Dripping Spring quartzite formation, Gila, Graham, and Pinal counties, Ariz. (fig. 44). Uranium minerals occur along fractures and disseminated in the Dripping Spring quartzite formation (pre-Cambrian Apache group) in two areas north of Globe, and from one of these areas a significant amount of uranium ore has been produced. Measurements of radioactivity in the Dripping Spring quartzite were abnormally high at several locations, and although no new occurrences of uranium minerals have been discovered, the area favorable for more intensive search has been considerably expanded.

3. Weaver Mountains, Yavapai Co., Ariz. (fig. 44). Two occurrences of radioactive material were discovered in an area underlain by an abnormally radioactive granite. One occurrence is in a pegmatite being mined for scrap mica. Small quantities of uranium and thorium minerals are concentrated in isolated pockets; possibilities for production are considered poor. The other occurrence is in a narrow torbernite (?)-bearing zone that extends 30 feet along the footwall of a gold-quartz vein. The uranium content is inferred from field measurements to be 0.05 percent or less.

4. Black Rock district, Yavapai Co., Ariz. (fig. 44). During a preliminary reconnaissance of the Black Rock district, anomalous radioactivity was detected at a number of localities. A more extensive reconnaissance is planned.

5. Tyrone district, Grant Co., N. M. (fig. 44). As part of an exploration program for copper in the Tyrone district, the Phelps Dodge Corporation churn-drilled a number of holes in granite and quartz monzonite. The Survey obtained gamma-ray logs of many of the holes and found some to be abnormally radioactive. The radioactivity is caused

partly by unusually large concentrations of radon gas. At the surface, abnormal radioactivity was detected in outcrops of fracture zones and in remnants of discarded drill sludge. No uranium minerals were identified. The uranium content is below that required for commercial ore, but the possible presence of primary uranium minerals in depth could improve the grade. The area outlined by drill holes with gamma-ray logs that show abnormal radioactivity is about one-third square mile; surface reconnaissance indicates that the area underlain in part by radioactive material is even larger. Available information is insufficient to permit even tentative grade and reserve tonnage estimates.

The discovery of uranium at Tyrone and 4 miles west of Tyrone suggests that the area between the previously known occurrences in the Black Hawk and White Signal district is favorable for uranium prospecting.

Plans for the next 6 months include the above-mentioned compilation of data on the distribution, mineralogy, and geologic features of occurrences of radioactive material in the Southwest as well as further, more detailed work in the Weaver mountains, Black Rock district, and Tyrone district.

New Mexico
by Roy Griggs

In T. 2 N., R. 10 W. and R. 11 W., near Datil, Catron County, anomalous radioactivity was noted in the lower parts of sandstone beds and the upper part of underlying black shales in a cuesta-forming member of the Mesaverde formation of Upper Cretaceous age. Faint traces of activity occur over a distance of about ten miles along the strike, and samples from secs. 11 (?) and 14, T. 2 N., R. 11 W. and secs. 18 and 26 (?)

T. 2 N., R. 10 W. show as much as 0.1 percent eU. Mineralization is limited generally to zones less than 3 inches thick, but at one locality the mineralized rock, in a small sanstone lens, is as much as 1 foot thick.

Anomalous radioactivity on the order of 0.003 - 0.005 percent eU was noted in three areas in north-central New Mexico: in the Cerrillos mining district, 15 miles southwest of Santa Fe, in kaolinized and silicified intrusives in secs. 20, 28, and 34, T. 15 N., R. 8 E., and sec. 4 (?), T. 14 N., R 8 E.; in the Glorietta district, 15 miles southeast of Santa Fe, in red-bed copper deposits in the Sangre de Cristo formation in sec. 14, T. 16 N., R. 11 E. and in sedimentary iron ore in the San Andres formation in sec. 14, T. 15 N., R. 11 E; and in the northeastern part of the state near Las Vegas and Raton, in thin bentonite beds in the Graneros shale 1/4 mile east of Las Vegas, in carbonaceous shale in the upper part of the Purgatoire (?) formation and in thin sandstone beds in the Morrison formation south and southeast of the town. About 25 miles southeast of Raton radioactivity of the same order of magnitude is present in monzonitic and syenitic sills emplaced in Jurassic and Cretaceous sediments; these sills are abundant over an area of about 100 square miles.

In addition to the localities listed above, slight radioactivity was noted in the Mancos shale at its contact with an intrusive in the Cerrillos mining district, and in a coal bed 1 to 2 feet thick in the Madera limestone north of Serafina postoffice, in sec. 8, T. 14 N., R. 15 E.

Utah-Nevada district

by A. O. Taylor

During the report period 39 mines and prospects in twelve mining districts and four unorganized mining areas were examined for radioactive materials. Localities examined in the following areas were not abnormally radioactive: Washington and State Line districts, Utah; Kingston, Bruner, Quartz Mountain, Washington, Union, Yerington, and Fairplay districts, Nevada. The Wah Wah mountains and the Erickson and Newton mining districts in Utah and the Reese River mining district in Nevada contain radioactive deposits. About 225 square miles in the Wah Wah mountains and about 60 square miles in the Tushar mountains, Beaver County, Utah, were mapped by reconnaissance geologic methods.

Wah Wah Mountains, Utah

Geologic mapping in the Wah Wah mountains disclosed a thrust fault involving Paleozoic rocks. Rhyolite porphyry dikes and plugs were injected along structures developed in the lower plate of the fault and locally the contacts between the intrusions and the sediments are brecciated and offset by minor faults. It is in these places that the known fluorite-uranium deposits in the area have been found. All of the rhyolite porphyry intrusions are abnormally radioactive. Their eU content falls in the range of 30 to 50 ppm.

Two low-grade uranium occurrences were discovered about half a mile northeast of the Staats mine. One occurrence is a vein consisting of highly altered rhyolite porphyry containing small amounts of fluorite and autunite. Samples assayed contained from .027 to .030 percent U. The other occurrence is at the contact of rhyolite porphyry and dolomite. Irregular masses of iron oxide gossan are exposed along the contact over a distance of about 1,000 feet. Samples taken from the most highly radioactive areas contain .015 to .030 percent U.

The original character of the sulfide mineralization in the gossan deposit is unknown. No secondary lead, zinc or copper minerals were observed. Before oxidation the iron gossan deposits may have been composed predominantly of pyrite. If so, considerable amounts of uranium may have been removed in solution as uranium sulfate during the oxidation of the pyritic masses.

Surface and underground geologic mapping at the Staats mine yielded structural data that was used in the discovery of a fluorite orebody under a DMEA exploration program. Although parts of the mine contain autunite and fluorite, the new fluorite orebody is not appreciably radioactive. Assays from uraniferous areas in the mine vary from .01 to .15 percent U. A few tons of ore containing from .10 to .15 percent U could be obtained by hand sorting.

Newton District, Tushar Mountains, Utah

Radioactivity traversing and reconnaissance geologic mapping on the western flank of the Tushar mountains between Indian Creek and North Creek failed to discover new uranium deposits. The DMEA exploration program in progress at the Mystery-Sniffer mine on Indian Creek has also had negative results.

Sheep Rock Mountains, Utah

The Erickson mining district in the Sheep Rock mountains contains four types of radioactive deposits. Staatz (TEM-162) has described copper, fluorite, uranium deposits in the area. Quartz pegmatite deposits have been found that contain up to .31 percent Th. A granite stock containing disseminated beryl, now being explored under a DMEA contract, is estimated to contain about .005 percent eU. The occurrence of abnormal radioactivity in the stock is unknown. If the stock is eventually mined for beryl its radioactive content may be of some interest as a by-product.

Uranium was recently discovered on the Silver King claim group in the Erickson district by a prospector. The uranium is in veins associated with copper, silver, cobalt, and manganese minerals. Ore grade material is present. AEC personnel have recently completed a surface geologic map covering the new area.

Reese River Mining District, Nevada

Prospectors have discovered uranium in the Reese River mining district a few miles south of Austin, Nevada. The deposit on the Early Day claim consists of autunite and torbernite disseminated in shear zones parallel to the bedding of Ordovician (?) metasediments. The metasediments appear to be xenoliths in granodiorite or quartz monzonite that is argillized and sericitized at its contacts with the metasediments. The owners are driving an adit collared in the intrusion that will probably show whether the deposit is confined to the metasediments or extends into the intrusion. AEC personnel have mapped and sampled the deposit.

The dumps of the old silver mines at Austin have been examined for radioactivity with negative results. The old silver mines are about four miles north of the new discovery of uranium.

Northwest district
by F. C. Armstrong

During the reporting period several areas and individual properties in the northwest district were examined for radioactive materials:

Central Idaho placer deposits

Hull's Big Creek placer, Valley Co., Lakow Flats placer, Boise Co., and Dismal Swamp placer, Elmore Co., were examined for the presence of radioactive black minerals, monazite, and columbium-bearing minerals. None of these deposits is considered a potential source of uranium, thorium or columbium.

Three samples of black gravels were taken from the jigs on the Tyee Mining Company's gold dredge on Red River southeast of Elk City, Idaho Co., Ida. Euxenite, brannerite, and samarskite (?) have been identified in the jig concentrate. The operator states that approximately 1000 pounds of black gravels are recovered in the jigs per eight-hour shift from about 800 cubic yards of gravel. Nothing is being done to recover the uranium, and the jig concentrate is being returned to the river bed.

The Garm-Lamoreaux mine, Lemhi Co., Idaho

Samples from two of the old dumps indicate the presence of pitchblende-bearing vein material. A TEMR, now in preparation, recommends rehabilitation of Tunnel no. 3 and development work on the Lamoreaux vein.

Lemhi Pass thorium area, Idaho-Montana

A DMEA underground exploration project was continued on the Wonder Lode claims during the field season. Drifting disclosed thorium-rich lenses in a large fault zone. A new thorium occurrence, the Perron claims, was found during the summer on the north side of Agency Creek one-tenth mile above the Copper Queen mine turn-off, Lemhi County, Idaho. Two samples from this deposit assayed 0.21 and 0.22 percent eU and 0.005 and 0.005 percent U, respectively.

The thorium mineralization appears to be confined to zones of red alteration in the Belt rocks.

Idaho-Montana fluorite deposits

Reconnaissance for radioactivity of two fluorite deposits west of Challis, Ida., indicate that they are not potential sources of uranium.

One sample from a one-foot, dark band in the north ore body at the Crystal Mountain fluorite deposit, Ravalli County, Montana, assayed 0.13 percent eU and 0.078 percent U.

Mineral Hill district, Lemhi Co., Idaho

Eight samples collected by Westvaco Chemical Division from the Mineral Hill district all contained less than 0.013 percent U. Previous analyses indicated 1.5 percent eU in one sample. Check analyses showed the abnormal radioactivity to be due principally to thorium-bearing monazite.

The monazite deposits appear to be small and discontinuous and would have to be mined by underground methods. Columbium-bearing rutile occurs in and near the monazite deposits, but does not appear to be present in economic concentrations.

North of the Salmon River between Dump and Moose Creeks, black, tabular allanite occurs sparsely in a small pink lens in the footwall of a quartz feldspar pegmatite. A sample from this lens assayed 0.35 percent eU. The chemical analysis has not yet been received.

Northern Cascades Mountains, Washington

Radioactive deposits have been reported from the west slope of Mt. Rainier and from Red Mountain, Chelan Co. Two samples of uraninite and coffinite, reportedly from the Northern Cascades, have been submitted to project personnel and probably will be investigated next spring.

Coeur d'Alene mining district, Shoshone Co., Idaho

Pitchblende occurrences at the Sunshine, Crescent, and Coeur d'Alene mines were examined. At the Crescent mine two channel samples across the radioactive occurrence assayed 0.054 percent eU, 0.048 percent U, and 0.033 percent eU, 0.026 percent U. Scintillometer traverses across the surface projection of the radioactive part of the Alhambra fault failed to detect abnormal radioactivity on the surface. A TEMR on this work is in preparation.

A preliminary study of the gross metal zoning in the Coeur d'Alene district indicates a copper-gold area in Montana east of the center of Coeur d'Alene district. The occurrence of autunite at the Waterhole property near Saltese, Mineral Co., Mont., and the zoning pattern suggest that the area between Mullan, Ida., and Saltese, Mont., may be a possible source of uranium.

Spokane Molybdenum mine, Ferry Co., Washington

A pitchblende-bearing veinlet occurs in the Spokane Molybdenum mine. Within the next few months the mine will be mapped geologically and the radioactive occurrences sampled.

Flathead quartzite, Montana

Uranium was discovered last summer by the AEC in the Flathead quartzite near Belfry, Carbon Co., Mont. Scintillometer traverses across approximately 7 miles of outcrop of Flathead lying disconformably (?) on the Belt series in the Horseshoe Hills, Gallatin Co., did not show any abnormal radioactivity. Where the radioactivity occurs the Flathead lies unconformably on Archean gneiss. Because of this, the areas where the Flathead is in contact with Archean rocks is considered more favorable for prospecting.

Naples, Idaho

Radioactive occurrences were discovered near Naples, Boundary Co., Ida., this past summer. Work to date does not indicate that this area is a potential source of uranium.

Other areas

Examinations of the Muscovite mine, Latah Co., and Ima mine, Lemhi Co., Ida., Consolidated Mines and Smelting Company's No. 3 mine, Ferry County, and Railway Dike mine, Stevens Co., Wash., indicate that these properties are not potential sources of uranium.

California district
by H. G. Stephens

Work during the period included (1) reconnaissance in the Modoc Plateau province, Modoc and Lassen Counties; (2) examination of the Coon claim, San Bernadino County; (3) evaluation of data from other properties; (4) a radioactivity check of more than 6,000 specimens in the collections of the California Division of Mines and the University of California, and (5) compilation of data and preparation of a report summarizing known radioactive occurrences in California.

Reconnaissance studies were made of mineralized areas and bedrock exposures in the Modoc Plateau province, Modoc and Lassen Counties. A total of 25 mines and prospects were tested for radioactivity. Outcrops of Tertiary volcanic rocks including rhyolite, rhyolite tuff and breccia, andesite, andesitic tuff and breccia, and basalt were examined for anomalous radioactivity. No material was found that appears to constitute a potential source of uranium or thorium. The exposures tested were essentially non-radioactive, and traverses of 430 miles of roads with car-mounted equipment yielded negative results.

The Coon claim, San Bernandino County, was the only new occurrence examined that showed significant radioactivity. The highest readings were taken along hard limy portions of the fine-grained calcareous sandstone; the lack of visible secondary mineralization suggests that a finely divided primary uranium mineral may be sparsely distributed in the rock. The material is not expected to have commercial value as uranium ore.

None of the seven additional properties examined showed significant amounts of anomalous radioacivity.

Of the more than 6,000 ore, mineral, and rock specimens in the collections of the California Division of Mines and the University of California, 168 were found to be significantly radioactive; this number includes 44 not previously known to be radioactive. Only 11 of the 168 specimens are from localities in California. The checking of the specimens produced leads justifying regional reconnaissance studies in the Foothill copper-zinc belt, Calaveras County, and the Gabilan Mesa area, Monterey County. Check of the collections of the California Division of Mines is complete; work on the University of California collection is in progress.

A report on regional reconnaissance in the Modoc Plateau province is in preparation, and the report summarizing known occurrences of radioactive minerals in California is in the final editing stage. During the next half-year period checking of the University of California collection will be completed, and regional reconnaissance in the Foothill copper-zinc belt, Calaveras County, and the Gabilan Mesa area, Monterey County, will be started.

RECONNAISSANCE FOR URANIUM IN ALASKA
by John J. Matzko

Reconnaissance in 1953

Twelve reconnaissance investigations were made in the 1953 field season. The preliminary results are summarized in table 9 and the localities are shown in figure 45. Brief statements on the more significant occurrences of radioactive material are given below.

Fowler prospect

Samples of limestone submitted by Fowler in 1951 contain 0.6 percent U (TEM-552,pp. 20-23). The sample location reported to be on Nikolai Creek in the foothills of the southern Alaska Range was visited briefly during the 1953 field season but no anomalous radioactivity was detected.

Resurrection Peninsula

A sandstone containing metatyuyamunite, submitted by Martin Goreson in 1952, contains 1.7 percent U (TEM-552,pp. 34-35). Goreson reported that he found the sample at the foot of Spoon Glacier in the valley of Likes Creek on the west side of Resurrection Penninsula. An attempt during the 1953 field season to duplicate the samples or locate the source failed.

Peace River area

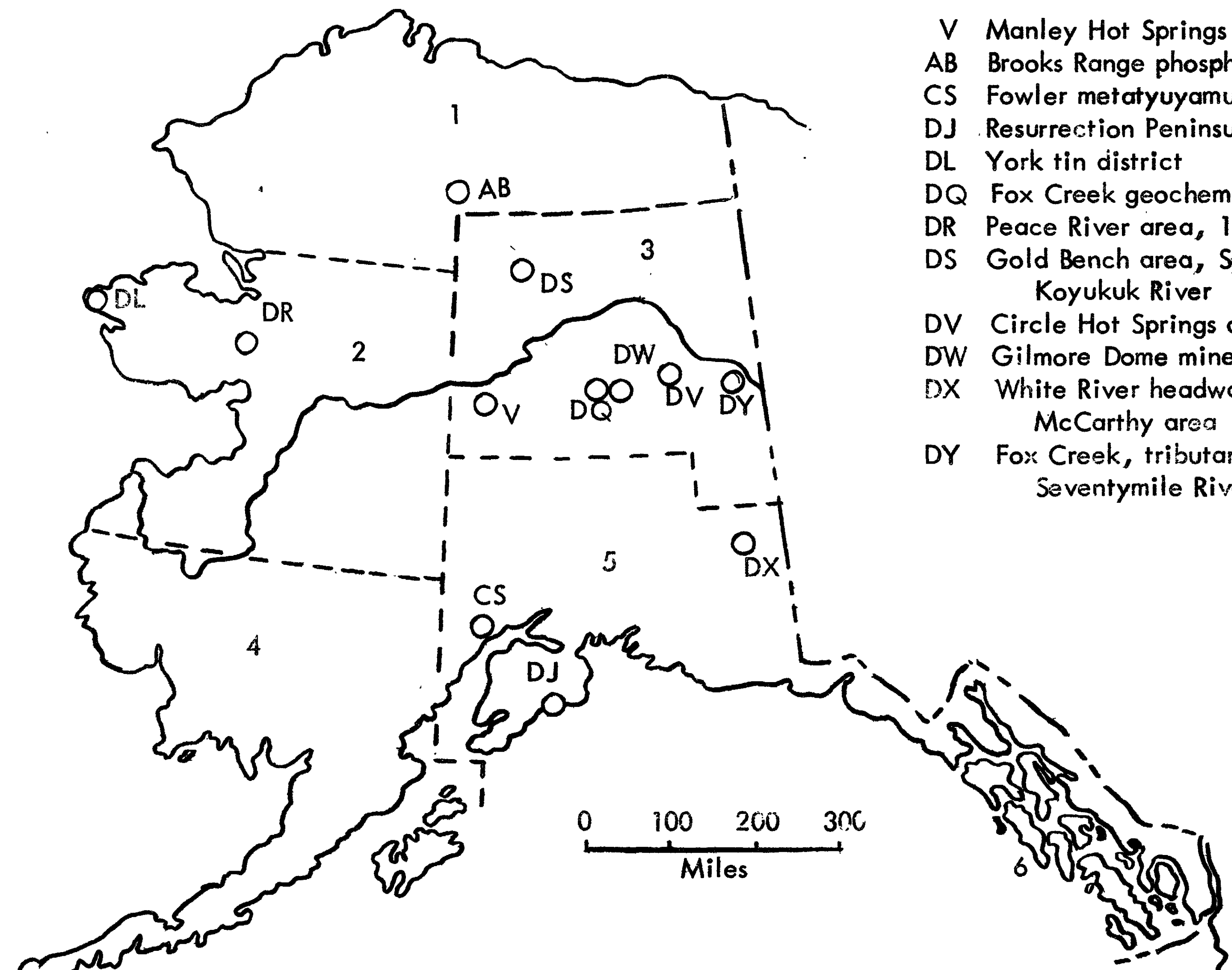
An unsuccessful attempt was made in 1953 by prospectors to locate the bedrock source of uranothorianite and gummite reported in stream concentrates (TEM-355).

Table 9.--Summary of reconnaissance for uranium and thorium in Alaska June 1 - November 30, 1953

Region Locality	Designation on fig.	Type of deposit examined, sought for or reported	Maximum radio-activity noted eU percent
<u>Northern Alaska</u>			
Brooks Range phosphate	AB	Uraniferous phosphatic member of the Lisburne formation	0.024
<u>West-central Alaska</u>			
York tin district	DL	Radioactive minerals in tin placers at Cape Mountain and in lodes at the Lost River tin mine	.005
Peace River area	DR	Search for bedrock source of uranothorianite	.8
<u>East-central Alaska</u>			
Gold Bench area, South Fork Koyukuk River	DS	To locate the bedrock source of uranothorianite and associated sulfides in placers	.18
Circle Hot Springs area	DV	Geochemical techniques applied to locate the bedrock source of uranothorianite	.01
Fairbanks district Gilmore Dome mine	DW	Scheelite mineralization in schist	.001
Fox Creek, tributary to Goldstream Creek	DQ	Veins of uraniferous galena and associated sulfides and location of concentrated uraniferous zones as determined by geochemical techniques	.025
Manley Hot Springs area	V	Radioactive placer concentrate from Miller Creek, submitted by U. S. Bureau of Mines	.07
Fox Creek, tributary to Seventymile River	DY	Uranothorianite in placer concentrate submitted by Territorial Department of Mines	.01
<u>Southern Alaska</u>			
Fowler prospect	CS	Metatyuyamunite in limestone submitted by prospector	.03
Chitistone River, Chitistone Pass, Skolai Pass and the headwaters of the White River, McCarthy area	DX	Greenstone, limestone, shale and sandstone examined by air-borne scintillometer. Canyon of Chitistone River gave a reading of about 10 times the background count.	

Table 9.--Summary of reconniassance for uranium and thorium in Alaska June 1 - November 30, 1953 (continued)

Region Locality	Designation on fig.	Type of deposit examined, sought for or reported	Maximum radio-activity noted eU percent
Southern Alaska (continued)			
Resurrection Peninsula			
Richardson prospect, on divide between Likes and Fourth of July Creeks	DJ	Yellowish uraniferous (?) sand-stone reported by prospector was found to be iron-stained graywacke	0.001
Goreson prospect, valley of Likes Creek, at the foot of Spoon Glaciers	DJ	Metatyuyamunite-bearing sandstone	1.5



EXPLANATION

V	Manley Hot Springs area
AB	Brooks Range phosphate
CS	Fowler metatyuyamunite prospect
DJ	Resurrection Peninsula
DL	York tin district
DQ	Fox Creek geochemical prospecting
DR	Peace River area, 1953
DS	Gold Bench area, South Fork, Koyukuk River
DV	Circle Hot Springs area
DW	Gilmore Dome mine
DX	White River headwaters, McCarthy area
DY	Fox Creek, tributary to Seventymile River

Regions

1 Northern Alaska
2 West-central Alaska
3 East-central Alaska
4 Southwestern Alaska
5 Southern Alaska
6 Southeastern Alaska

Figure 45.--LOCATION OF TRACE ELEMENTS PROJECTS IN PROGRESS IN ALASKA DURING FISCAL-YEAR 1954

Gold Bench area

A placer sample containing uranothorianite associated with hematite, bismuth, platinum, copper, lead, tin and tungsten minerals from Gold Bench in the Koyukuk-Chandalar region, east-central Alaska contains 0.18 percent eU (TEM-552, pp. 12-14). An attempt to locate the source of the uranothorianite or to duplicate the sample was unsuccessful.

General information

A heavy sand concentrate submitted by a prospector in southern Alaska, contains 35 percent eU and 19 percent U. The chief radioactive mineral is uranothorianite. In addition, the concentrate contains traces of sulfide minerals.

In 1949 the Territorial Department of Mines submitted a radioactive hematitic sample to the AEC containing 0.05 percent eU (TEM-235, pp. 63-64). In 1953, a prospector in southeastern Alaska claimed to know the source of this sample, but samples collected from the reported site by a Survey geologist accompanying the prospector contain only 0.002 percent eU.

Summary of laboratory work at Fairbanks during field season 1953

Radioactivity determination, equivalent uranium	354
Identifications, mineral	448
spectroscopic	255
Heavy liquid separations	50
Phosphate determinations, rapid method	81
Alpha plate studies	19

ANALYTICAL SERVICE AND RESEARCH ON METHODS

Service
by Jack Rowe

Analytical work and sample inventory for the period June 1, 1953 - November 30, 1953, are listed below.

Table 10.--Analytical work and sample inventory, June - November 1953

Project or material	Chemical determinations		Spectro-graphic determin-ations	Radio-activity determin-ations	Samples re-ceived	Samples on hand at end of Nov.*	Samples on hand as of June 1,1953
	Uranium	Other					
Washington Laboratory							
SE phosphates	960	971	3,468	2,890	4,224	7,535	10,189
AEC, New York	427	314	6,944	12	342	22	75
Fuels Branch	2,368	531	39,850	2,310	4,151	3,353	1,284
NW phosphates	-	26	-	-	87	124	63
Sea waters and bottoms	140	140	680	-	39	240	341
Alaskan samples	21	12	57	24	106	91	-
SE monazites	-	-	3,473	-	114	71	2,087
Uranium in waters	35	19	1,700	-	177	143	18
G & P mineral	162	79	10,677	-	50	82	-
Miscellaneous	494	357	11,084	177	453	154	153
Geochemistry of U	511	236	13,351	4	311	795	128
Totals	5,118	2,685	91,284	5,417	10,054	12,610	14,338
Denver Laboratory							
Colorado Plateau	2,147	5,647	36,912	3,208	2,513	1,027	1,100
Plants & soils	3,370	229	-	24	2,643	1,645	121
Oil well drilling	155	798	3,945	95	34	102	1,317
SE phosphates	-	-	-	626	56	626	626
AEC samples	1,421	1,398	3,091	1,592	1,677	563	1,011
Reconnaissance	1,269	4,098	24,975	1,947	4,404	3,143	2,055
Fuels Branch	251	131	2,923	190	1,346	1,139	221
Miscellaneous	55	70	5,919	124	532	383	138
Totals	8,668	12,371	77,765	7,806	13,205	8,627	6,589
Grand Totals	13,786	15,056	169,049	13,223	23,259	21,237	20,927

* Includes internal samples not shown in "Samples received" column.

Research

Radioactivity analysis and research

Equipment and methods, Washington laboratory, by F. J. Flanagan

The coaxial tube and sample holder used in the laboratory for the past several years has been improved by cementing the thin-walled Geiger-Muller tube coaxially into the male half of a ground glass joint, using Rohm and Hass "Paraplex" or Pittsburgh Plate Glass "Selectron" as the cementing agent. The joint is cut off to a length of about $3\frac{1}{2}$ inches and the tube leads soldered to a four prong base, firmly sealed to the joint with deKotinsky cement. The female half of the joint is then fitted to the male and the holder is ready for operation.

Equipment and methods, Denver laboratory, by J. N. Rosholt

Radiochemical research on a method of measuring thorium and ionium has been essentially completed and semi-routine analyses are being made. Calculations and test samples check with known methods.

A radon apparatus with a capacity of four samples per day has been completed and calibrated. Expansion to a six-sample per day apparatus is planned and preliminary work completed.

A very sensitive alpha scintillation counter for eU determinations has been completed and is capable of determinations in the range of 0.00003 to 0.01 percent. This is being used in conjunction with the radiochemical work. The radiochemical analyses besides being performed as a routine service are being studied on a long range basis to ascertain the distribution of natural radioactive isotopes in ores exhibiting disequilibrium.

Thorium analysis, by F. E. Senftle

Although no experimental work for measuring thorium by a photographic technique has been done, the theoretical phase has been completed. TEI-374, "Theoretical alpha star populations in loaded nuclear emulsions," by F. Senftle, T. Farley, and L. Stieff has been transmitted. The tables and method for simplifying calculations by Bateman's equation have been expanded to include the neptunium series and the complete paper "Tables and method of simplifying calculations by Bateman's equation," by F. Flanagan and F. Senftle has been sent to Nucleonics for publication.

Work has continued on the emanation method of thorium analysis of zircon but considerable difficulty has been experienced by alloying of the sample with the filament at the high temperature needed to emanate the thoron. Little progress can be made until this problem is overcome.

Metamictization of zircons, by F. E. Senftle

After several weeks bombardment of the zircons at the Naval Research Laboratory, it became apparent that the polonium source was not large enough to produce sufficient radiation damage in a reasonable time to get a change in X-ray properties. Arrangements were made to use a two curie source at the Oak Ridge National Laboratory. Fresh zircons were prepared in a special holder and the sample was allowed to irradiate for about four months. Preliminary X-ray analysis showed a significant change in the lattice structure and it appears that artificial metamictization has been produced.

Several samples of fresh zircon were prepared for deuteron bombardment in the Washington University cyclotron. The samples were irradiated but no significant lattice change was observed even in the sample which was given the largest dose of deuterons. The effective deuteron dosage was about 50 times less than the alpha dosage at Oak Ridge National Laboratory. Moreover, the damaging effect of an alpha particle will be greater than that of a deuteron because of mass difference.

Tables for calculation of neutron activities, by F. E. Senftle

The compilation of a table for the calculation of radioactivies of different elements subjected to neutron irradiation has been undertaken and essentially completed. This will be of help in calculating the expected activities of any materials it is desired to irradiate in the pile either for tracer work or for radiation damage experiments.

Activation analysis for isotopic abundances, by F. E. Senftle

Theoretical calculations have been made to see if it is feasible to make isotopic abundance analyses by a radioactivation technique. The method appears applicable to about 15 elements and Oak Ridge National Laboratory has agreed to try the method on two copper samples as a preliminary investigation.

Spectrography

Washington laboratory, by C. L. Waring

Spectrographic methods were developed or improved to help solve several mineralogical problems such as the mineral identification of small samples or fine grain mixtures from which 1 to 10 mg is hand picked in a reasonable time. In one sample thought to be hewettite, sodium was found which led to the discovery of a sodium analogue of hewettite. The methods also helped to identify pairs or groups of related minerals (isostructural series) which have similar X-ray patterns. As an example, torbernite (Ca-U-P) and zeunerite (Cu-U-As) were identified.

Spectrographic methods were also developed or improved to aid and supplement the chemical analysis of rocks. The average chemical analysis of an igneous rock includes determinations of only 8 to 12 elements. Ba, Sr, Li, Ti, Mn, Cr, Ni, and Co are not determined unless specifically requested because of the difficulty and time required to conduct these analyses. The elements are now being determined spectrographically using small samples.

The development of spectrographic techniques to aid in determining the chemical composition of uranium minerals, such as bassetite, and uranospathite were improved and applied.

Studies completed and on which reports have been published this period are as follows:

1. Method for determination of small amounts of rare earths and thorium in phosphate rocks, Waring, C. L. and Mela, H., Analytical Chemistry, v. 25, p. 432-5, 1953.

2. Semiquantitative spectrographic method for the analysis of minerals, rocks and ores, Waring, C. L. and Annell, C. S., Analytical Chemistry, v. 25, p. 1174-9, 1953.

3. A spectrographic method for determining trace amounts of lead in zircon and other minerals, Waring, C. L. and Worthing, H., American Mineralogist, v. 38, nos. 9-10, pp. 827-33, 1953.

4. Zoned zircon from Oklahoma, Larsen, E. S., Waring, C. L., and Berman, J., American Mineralogist, v. 38, nos. 11-12, 1953.

Reports in progress are as follows:

1. The use of spectrography in mineralogic and geochemical problems.
2. The automatic scanning of spectrographic semiquantitative plates. (microphotometric scanning procedure)
3. The semiquantitative spectrographic analysis of low-rank coals.

Use of controlled atmospheres for photographic spectra in the region of greatest cyanogen band interference has been resumed. Justification for further work along this line is suggested by the fact that thirteen of the elements have their most sensitive arc lines occurring in this region and seventeen elements have their most sensitive spark lines listed in this range. Included in these elements are Nb, Co, Ga, In, Mn, Mo, Pb, Zr, and thirteen rare earths.

Tests on the applicability of the "addition method" of preparing spectrographic standards to problems existing in the laboratory have shown some progress. Three points that must be investigated before applying the method are as follows:

1. The effect of self absorption.
2. Effect of compositional difference.
3. Correction for background.

If this method is found to be satisfactory, it will partially solve the always present problem of locating spectrographic standards of suitable matrix for various types of unknowns.

A new grating has been purchased for the Jarrell-Ash spectrograph to replace a faulty one. A special platform has been installed in the spectograph to permit the alternate use of either grating. This was necessary in order to keep the test requests moving while the new grating is being standardized. The focus of the new grating has been located, and some test work has been completed to determine the proper exposure conditions for semi-quantitative work. The sensitivities of some lines should be increased because the shape of the rulings of the new grating was controlled to throw approximately 70 percent of the light in the first order spectrum (2100 to 4700 angstroms).

The microphotometric scanning procedure has shown some progress this period. The method covers the standard 68 element procedure with the exception of Co, Sr, Ni, Sc, Y, Yb, and Zn. Work is in progress to include these elements. In the microphotometric scanning procedure the spectral lines of the samples are compared with the aid of the Leeds and Northrup microphotometer, to lines produced by chemically analyzed or synthetic standards.

During this period 87,178 qualitative, semiquantitative and quantitative determinations were completed spectrographically.

Denver laboratory, by A. T. Myers

A three-meter Hilger grating spectrograph was delivered during this report period and is being installed, adjusted and tested. When placed in operation this instrument will help carry an important part of our analytical work load.

Frequent checks have been made between spectrographic and chemical determinations and between the determinations of the Denver and Washington spectrographic laboratories. This work will be continued as a necessary part of checking the quality of analysis in the two laboratories.

During the past six months a total of 91,039 determinations were made on 1,698 samples submitted to Denver for analysis. Table 11 shows these totals distributed according to their source.

In previous periods, the sample load of the laboratory was largely for analysis of samples in relatively small lots and more or less on an individual basis. Now larger groups of samples have been collected and analyzed to study element distribution over an area or province. Thus, of

Table 11.--Spectrographic analysis of Raw Materials, Denver Laboratory
June 1 to November 30, 1953

Source of Samples	Total No. of Samples	Semi-Quan.		Quan.		Total No. of Detns.
		Samples	Detns.	Samples	Detns.	
Colo. Plateau Shales and Sandstones	741	741	44,427	0	0	44,427
AEC-Denver	35	29	1,419	6	6	1,425
AEC-All Other	49	49	2,862	0	0	2,862
Mineral Deposits, Reconnaissance	639	488	28,445	151	509	28,954
Fuels Branch	48	48	2,880	0	0	2,880
Taxpayer	1	1	60	0	0	60
Miscellaneous	185	177	10,408	8	23	10,431
Totals	1,698	1,533	90,501	165	538	91,039

741 samples submitted from the Colorado Plateau, nearly 700 were analyzed to determine the distribution of elements in mill pulps and sedimentary and igneous rocks from that province.

An essential part of making useful studies of this kind has been the development in our laboratory of a semi-quantitative method of analysis. This method reported results for sixty or more elements to narrower ranges of concentration than formerly, i.e. o.x- for 0.1 to 0.215 percent, o.x for 0.215 to 0.464 percent, and 0.x+ for 0.464 to 1.0 percent instead of o.x for 0.1 to 1.0 percent, and similarly for other orders of magnitude. A report on the techniques used in this method is in preparation.

Chemistry

Analysis of Raw Materials, Washington, by Irving May

A summary of the analytical work for the past six months and of the present sample load is as follows:

	Completed the past 6 months	On Hand not completed
No. of Requisitions	286	151
No. of Samples	3,346	4,121
No. of Determinations	6,926	6,321

The major portion of the routine uranium determinations were on Chattanooga shales. Because of the high precision required for these samples, quadruplicate determinations were made routinely. All of the uranium determinations for the new Chattanooga drillings have been completed. Concurrent with these determinations, splits of a shale sample were analyzed in a systematic pattern. Four hundred determinations were made and the data obtained is now being analyzed statistically. This study should provide valuable information on the grinding and splitting techniques and on the precision of the chemical determinations.

The leached zone program of the Florida phosphate project requires the services of several chemists. The samples involve uranium, phosphorus, calcium and aluminum determinations. The aluminum determination is the most laborious one and it is hoped that a faster method applicable to these samples will be developed shortly.

A spiking technique correction of quenching in the direct determination of uranium in waters was studied. It is now being used routinely with water samples and is resulting in a saving of time for these samples.

Cooperative studies are being conducted with the Denver laboratory of the reproducibility of the fluorimetric method for uranium. Irving May visited the Denver laboratory and while there assembled and wired a transmission fluorimeter. The fluorescence of several series of melts has been measured at various time intervals on fluorimeters in both Denver and Washington.

The present backlog of samples consists largely of lignite and leached zone samples. Most efforts are now being devoted to reducing the backlog of samples on hand. Studies have been made of analytical methods and techniques used in other laboratories and desirable variations thus discovered have been incorporated for use in analyses in our methods of analysis whenever advantageous.

Eight visitors from United States and foreign laboratories have visited the analytical chemistry laboratory for periods of several days to several months studying methods of analysis.

Analysis of Raw Materials, Denver, by L. F. Rader, Jr., and Wayne Mountjoy

Chemical analyses during the period June 1 to November 30, 1953, are summarized in the accompanying table and included in table 10. This summary includes service work and special analyses made by the combined projects, "Analysis of Raw Materials" and "Special Analysis of Raw Materials, Denver."

Uranium determinations represented 44.2% of the analyses, V_2O_5 20.8%, $CaCO_3$ 13.5%, Au, Ag, Cu, Pb, Zn, Fe, and Mn combined 14.0% and all other determinations 7.3% of the total analyses.

About 80% of the analyses were for the Plateau drilling program, Plateau plant program, AEC Denver programs, and Mineral Deposits Reconnaissance projects, namely, 38.2%, 17.9%, 14.7% and 19.1% respectively.

A new fluorimeter has been developed and constructed. This instrument incorporates the use of three electronic tubes in the circuit rather than a single photomultiplier tube commonly used in instruments of this type. In addition both a reflection type and transmission type head may be used interchangeably by the flip of a switch. This instrument also was designed for field use. Uranium quantities ranging from 0.01 microgram to 0.1 milligram may be read over the full range of the instrument without resorting to large dilutions or unusually small sample weights. Thus, a larger number of determinations of increased accuracy per unit of time should be possible with this instrument.

Eight samples of about 50 to 100 pounds each are being prepared for use as standard samples so that additional internal cross-checking, as well as cross-checking of various methods for different elements with outside laboratories may be carried out more precisely.

Samples obtained for this work to date are as follows: Two coals of different grade with respect to U, three carnotites of the following types: high carbonate ore grade, high carbonate low grade, low carbonate low grade, two schroeckingerites of low but different grade and one ore grade sample from Australia.

Table 12.--Chemical Analyses of Raw Materials, Denver
June 1 to November 30, 1953

Source of Samples	Number of Samples 1/	U 2/	V_2O_5	$CaCO_3$	Heavy Metals 3/	All Other Elements	Total Number Analyses
Plateau shale and sandstone	2,578	1,430	2,219	1,695	15	241	5,600
Plateau plants and soils	2,123	2,335	56	14	-	217	2,622
Oil well drillings & related samples	118	118	-	-	-	304	422
AEC, Denver	1,128	915	239	173	748	83	2,158
AEC, all other	582	534	-	-	26	3	563
Mineral Deposits Reconnaissance	1,377	817	480	105	1,211	192	2,805
Fuels Branch	282	276	54	-	49	34	413
Taxpayers' Samples	20	44	9	-	-	1	54
Miscellaneous	18	15	-	-	12	2	29
Total	8,226	6,484	3,057	1,987	2,061	1,077	14,666

1/ Includes only samples analyzed chemically.

2/ Differences between number of samples and number of uranium analyses are due either to cut-off values that make analyses of low grade samples unnecessary, or to multiple analyses on the same sample for a specific reason.

3/ Au, Ag, Cu, Pb, Zn, Fe, Mn

GEOCHEMICAL AND PETROLOGICAL RESEARCH ON BASIC PRINCIPLES

Distribution of uranium in igneous complexes

by David Gottfried for E. S. Larsen, Jr.

Investigations were continued on the distribution of uranium in rocks of several petrographic provinces. A total of 300 uranium determinations on 150 rock samples have been completed on carefully selected rocks from the following areas:

Southern California Batholith
Sierra Nevada
Idaho Batholith
San Juan Lavas
White Mountain Magma Series, New Hampshire
Front Range - Colorado

These igneous complexes underlie vast areas and are fairly typical of the average rocks exposed in the earth's crust. A general comparison of these areas indicates that for rocks of similar composition, the Southern California, Sierra Nevada, and Idaho batholiths are similar in uranium content. The distribution of uranium in the San Juan lavas appears to be non-systematic and a plot of their uranium content against their composition is erratic. The White Mountain magma series is highest in uranium content, approximately twice that of the Southern California batholith. These soda-rich granites contain from 10 to 14 ppm uranium. A study of their accessory minerals showed abundant and highly radioactive zircon, monazite, xenotime, allanite, pyrochlore, and the rare mineral chevkinite. The Front Range granites appear to contain 1½ times more radioactivity than the Southern California batholith. To determine the variability of uranium content in an apparently uniform rock type, a twelve mile traverse was made across a stock of the Boulder Creek granite near Boulder, Colorado. Samples were collected at $\frac{1}{2}$ mile intervals. The uranium content of the granite at the contact was 15 ppm U, and gradually decreased to 1.0 ppm U for the sample, 12 miles away from the contact.

Mono-mineralic concentrates of the major and minor accessory minerals have been made on almost all of these rocks. In view of the large number of uranium determinations required, only a few of the major minerals have been analyzed individually for uranium. The radioactivity of the accessory minerals has been studied in greater detail, as they contribute significantly to the total radioactivity of the rock. This has been made possible by alpha counting techniques which measures accurately and rapidly the radioactive content of these minerals. Among all the accessories, zircon is most common to all the igneous rocks thus far studied, although monazite, xenotime, and thorite appear to be more common than previous work had indicated. In addition the rarer radioactive minerals such as pyrochlore and chevkinite were found in granites of the White Mountain magma series. The radioactivity of the zircons separated from a related group of rocks such as the Southern California batholith has been investigated. There is a marked increase of the alpha activity of the zircon as the rocks from which they were separated became more acidic. This is readily apparent in table 13 where the zircon activity measurements are recorded in conjunction with zircon age determinations made on the same rocks.

As an outgrowth of these investigations the zircon-age method has been refined and perfected and extended to include the other accessories such as zenotime and monazite. In view of the great need for such a widely

Table 13.--Age and radioactivity of zircons from the Southern California Batholith

Locality		alphas/mg/hr	Pb(ppm)	Age (MY)
	Type Rock -- Quartz diorites			
G-33	Mt. Wilson	143	7	112
Z-7	Lakefork	646	30	115
G-13	La Posta	594	28	113
G-30	Palm Springs	327	14	108
S-1	Lakeview	183	10	130
G-48	Stonewall	545	21	91
G-10	Aguanga	280	10	86
G-3	Mountain Center	194	9	111
G-11	Green Valley	160	5	75
	Average 9 zircons	341	15	105
	Granodiorites			
Z-16	Woodson	1235	50	97
Z-20	Woodson	786	29	114
Z-17	Mt. Hole	1204	46	92
S-6	Woodson	1180	46	92
S-2	Woodson	433	22	122
G-32A	Woodson	457	22	116
	Average 6 zircons	897	36	106
	Granites			
Z-15	Rubidoux fine	2672	106	90
	Rubidoux coarse	725	48	130
	Rubidoux coarse	2700	106	94
	Average 3 zircons	2030	85	105

applicable age method and the great number of age requests, the U. S. Geological Survey has recently undertaken a program to carry out further research on this phase and handle future requests for age determinations.

Field work during this period consisted of collecting igneous rock samples from the Border Batholiths of northern Washington, Columbia River basalt, recent lavas from Crater Lake, Oregon and Lassen Volcanic National Park.

Investigations in western Montana on the Boulder Batholith and studies of the three older magma series in New Hampshire including the Highlandcraft (Ordovician), Oliverian (Devonian), and New Hampshire (Devonian) have continued. Through cooperation with field geologists, samples have been collected from the Coast Range of California and the Sierra Nevada.

During the remainder of the fiscal year laboratory studies of selected samples from New England and Montana will continue. In view of the need for more uranium data on minerals additional determinations will be made.

During the report period 651 chemical determinations were made on 431 samples. The colorimetric method for the determination of thorium in zircons has been successfully applied to a variety of types of sample materials. A few minor difficulties that occurred in the application of this method to various materials have been successfully eliminated, including interference of large amounts of silica by a treatment with HF. In the application of this method to thorium determination in bostonite, difficulties were encountered by the precipitation of cryolite from the sample solution. The method was modified by the removal of aluminum from the sample by a Na_2O_2 sinter in platinum, thereby eliminating the precipitation of cryolite. Occasionally the mesityl oxide used in the extraction of thorium became emulsified and the organic liquid would not separate cleanly from the aqueous layer. This difficulty was overcome by the use of cerium instead of lanthanum as a carrier in the precipitation of ThF_4.

With an aim toward lowering the limits of the amount of thorium determinable by this method, a study was made of the reproducibility possible in the range of 3 to 6 micrograms of thorium per 25 ml. volume. Results were found to agree within 10 percent even in this low range.

Reports:

Larsen, E. S., Jr., Berman, J., and Waring, C. L., Zoned zircon from Oklahoma, American Mineralogist, vol. 38, nos. 11-12, pp. 1118-1125, 1953.

Larsen, E. S., Jr. and Phair, G., Distribution of uranium in igneous rocks, to be included in volume on Nuclear Geology.

Hurley, P. and Fairbairn, H., Radiation damage in zircons: A possible age Method, Bull. G.S.A., vol. 64, no. 6, 1953.

Geochemical distribution and migration of helium in rocks, Informal internal report.

Gottfried, D. and Neuerburg, G., Age of the San Gabriel anorthosite massif. The age and relationships of radioactivity, lead content, and physical properties of zircon crystals from Ceylon, delivered at 1953 American Geophysical Union meeting.

Publications in process:

1. Method for determining the age of igneous rocks.
2. Distribution of uranium in rocks and minerals of the Southern California Batholith.
3. Pre-Cambrian rare earth mineralization in Mt. Pass District, California.
4. Chevkinite from Devils Slide Syenite, New Hampshire.

Weathering, transportation, and redeposition of uranium
by R. M. Garrels

Four channel samples were collected from mines in the vicinity of Paradox Valley, Uravan district, Colo., to illustrate key relations between "blue-black" and "carnotite" ore. The samples are being examined chemically to determine gross oxidation state, and mineralogically to determine phases present and their genetic relations. The tentative conclusion is that at least some "carnotite" ores are derived by weathering of an original montroseite (V_2O_3), uraninite (UO_2), and pyrite (FeS_2) association.

Apparatus for measuring and recording pH and oxidation potentials has been received, assembled, and calibrated. Some runs have been made using one reaction vessel; full scale operation awaits multi-channel cables and connector boxes. Complete chemical analyses, X-ray patterns, and electron photomicrographs have been made of six vanadium-bearing clays from various localities in the Salt Wash sandstone. All are hydrous micas; vanadium content ranges from 1 to 20 percent. Vanadium is present as V^{+4} and V^{+5}; no V^{+3} has yet been discovered. Tentative conclusion is that vanadium substitutes for aluminum in the clay structure.

A theoretical paper has been completed on the stability relations among the vanadium oxides in water at 25°C (Am. Miner., vol. 38, pp. 1251-1265), and a second paper on the uranium oxides is nearly completed. A bibliography of information on the solubility of uranium and vanadium minerals in water solutions is being accumulated.

Work will continue chiefly on (1) mineralogic and chemical changes as evidenced by the channel samples, (2) intensive study of composition of vanadium clays, and on the removal and emplacement of vanadium in the structures of the clays, (3) thermodynamic studies of the stability of the minerals in water, and (4) laboratory investigation of stability relations.

Mineral synthesis
by Irving Friedman

During the period covered by this report, work was continued on the system Na_2O-ZrO_2-SiO_2-H_2O. Even at temperatures of 500°C equilibrium is established quite slowly in this system, and it has been necessary to make all runs at least of 10 days duration. Previous work on this system has been in error as a result of non-equilibrium conditions caused by insufficient reaction time. The solid phases that appear at 500°C are baddeleyite, quartz, and elpidite. Various other sodium zirco-silicates appear as non-equilibrium (metastable) phases.

The system K_2O-ZrO_2-SiO_2-H_2O also was studied at 500°C. Zircon appears to be stable in this system at 500°. Efforts to synthesize hydroxyl apatite were successful. Future work will be directed toward growing crystals of sufficient size for study in connection with the phosphate project.

Two uranium minerals $K2(UO_2)_2 \cdot (PO_4)_2 \cdot 8\ H_2O$ and $K_2(UO_2)_2\ (AsO_4)_2 \cdot 8H_2O)$ have been synthesized for study in connection with the Colorado Plateau project.

One of the outstanding problems being investigated by the Survey is the formation of the uranium-vanadium deposits on the Colorado Plateau. As a part of this investigation, a study of the KOH-V_2O_5-UO_2-H_2O system, which contains carnotite, was started about 6 months ago.

At present, the system appears to consist of three phases - carnotite, "rauvite", and hydrous vanadium pentoxide. The pH of the solution determines which phase will precipitate; temperatures from 25° to 80°C have little effect on the stability fields.

The carnotite formed varies somewhat according to the pH of the solution. If the pH is below 6.5, the carnotite is a yellow, cryptocrystalline material. However, that formed above a pH of 6.5 may form either as a yellow flocculent material or as curled, shiny, micaeous plates. These plates are optically negative with 2V varying from 0° to 10°. The carnotite phase occupies a large area of the phase diagram.

At low pH values (about 1-5) carnotite becomes unstable and "rauvite" forms. Upon lowering the pH of these solutions, carnotite, which may form at first, redissolves and "rauvite" precipitates. Rauvite is a yellow flocculent material which changes to a deep orange color, sometimes a black color, on drying. The material is optically negative and has a 2V of approximately 40°. The X-ray diffraction pattern matched the characteristic pattern for rauvite ($CaO.2UO_3.5V_2O_5$-$16H_2O$). However, no calcium was present in the solutions from which this rauvite was precipitated.

Further lowering of the pH causes the precipitated "rauvite" to be redissolved. When the pH has fallen below one and evaporation has reduced the solution volume to less than a tenth of the original, a red scum of $V_2O_5 \cdot H_2O$ begins to form. This scum becomes black after being washed and dried.

It is believed that this study of the KOH-V_2O_5-UO_2-H_2O system and the delineation of the carnotite, "rauvite", and hydrous vanadium pentoxide phases will be of value in interpreting conditions of formation of these phases found in the field.

Isotope geology and nuclear research
by F. E. Senftle

Geochronology

The solid sample mass spectrometer has been completed and work on tuning and improving the resolution of the instrument continues. Preliminary analyses indicate results comparable to other laboratories, but further work is being continued to improve the resolution further. It is planned to get the resolution high enough to resolve the Pb^{204} peak in all cases before starting the bulk of the analyses for age determinations.

During September specimens were collected to complete the age studies on the Colorado Plateau. Excellent specimens of uranium ore were collected from the Temple Mountain district and the Mi Vida claim, Utex Mining Company in Utah, the Virgin Mine, Long Park district, Colorado, and from the Grants district, New Mexico. In addition a large suite of galena specimens was collected from the more important mining districts of the San Juan Mountains, Colorado. These samples are to be used in a comparison of the regional variations in isotopic composition of the lead in the San Juan galena, the age of which is known, with similar variations observed in the lead minerals from the uranium deposits in the Colorado Plateau.

Chemical analytical work was completed on 63 samples, and 38 samples of lead iodide were prepared. The Mass Assay Laboratory at Oak Ridge reported the isotopic analysis on 22 samples of lead iodide.

The Colorado Plateau age work is essentially completed. Rough drafts on two manuscripts have been prepared entitled, "The occurrence and properties of metatyuyamunite, $Ca(UO_2)_2(VO_4)_2.6\text{-}8H_2O$", and "Coffinite, a new uranium mineral." TEM-647 entitled, "Preliminary description of coffinite, a new uranium mineral" has been transmitted and is being submitted to the American Mineralogist for publication in Notes and News.

A paper entitled "Isotopic composition of lead in lead minerals from the Colorado Plateau" by L. R. Stieff and T. W. Stern was presented a the 1953 meeting of the Geological Society of America. A manuscript of the same title has been written and is now being processed for publication. The conclusions of this regional study of the systematic changes in isotopic composition of lead from Plateau lead minerals are as follows:

1. The systematic changes are a result of the addition of radiogenic Pb^{206} and Pb^{207} produced in the source area from which the uranium now found in the Mesozoic sediments was derived.

2. The added old radiogenic Pb^{206} and Pb^{207} was derived from a uranium source which is approximately 750 million years old.

3. The anomalously high Pb^{207}/Pb^{206} ages of the Plateau uranium ores are primarily the result of the presence of old radiogenic lead deposited with the uranium in the sediments rather than due to radon loss.

4. The Pb^{206}/U^{238} and Pb^{207}/U^{235} ages of the Plateau uranium ores will be lowered by corrections for the presence of old radiogenic lead. Thus a Tertiary age for the Plateau is strongly indicated.

Variations in natural isotopic abundances

Shortly after the gas-source mass-spectrometer was put in operation it was shut down for a month to take advantage of the summer field season for collecting samples. In July the spectrometer was again in operation and was tuned. Some erratic operation was traced to faulty parts. The gas preparation train has been completed and several samples have been prepared and run for hydrogen-deuterium ratios. Compared to an arbitrary standard (tap water) the following preliminary results were obtained from water extracted from the Jemez Mountains pearlite (Arroys-Honde) and enclosed clear "Apache Tears":

pearlite phase	2.3% H_2O	-2.5%
clear obsidian phase	0.2% H_2O	-2.5%

The water in the obsidian phase has either exchanged with the secondary pearlite water at an elevated temperature or the pearlite water is original magmatic water.

A cooperative project with the Woods Hole Oceanographic Institute has been undertaken to analyze about 150 samples of ocean water for hydrogen-deuterium ratios.

The theoretical work on diffusion has been written up for publication in Geochimica Acta and a note "Change of the isotopic abundance ratio within a sphere due to diffusion," by J. Bracken and F. Senftle has been to the Journal of Applied Physics. A talk entitled "Effect of diffusion on the natural isotopic abundance ratios" was given by F. Senftle at the meeting of the Geological Society of America in Toronto, Ontario, Canada.

Some preliminary experimental work on the variation of the Cu^{63}/Cu^{65} ratio in the silver phase of a Michigan copper-silver "halfbreed" due to a diffusion process is now being investigated. Pending the results of this initial work, further work to investigate diffusion as an isotope fractionation process will be undertaken.

Isotope geology of lead
by R. S. Cannon, Jr.

Investigation of leachable lead, thorium, uranium, and other components of igneous rocks continues in the geochemical laboratory at California Institute of Technology under the leadership of Professor Harrison Brown. This research has been reviewed recently in progress reports to AEC, at a mid-September conference in Washington, and in papers presented at the annual meeting of the Geological Society of America at Toronto. At the beginning of this report period Cannon and Neuerburg of the USGS and Silver of the CIT research staff formulated recommendations for geologic selection of a suite of 35 samples for leaching studies to yield information on the geologic history and provenience of the leachable materials. These and other samples for leaching studies, totalling about 50, were collected during the ensuing 6 months. In addition, an equal number of other kinds of samples for lead isotope work was collected, and Neuerburg has studied and described the petrography of about 75 rocks.

Several determinations by a member of the CIT group on isotopic composition of lead in critical samples were made: (1) lead in several meteorite samples, (2) lead in 3 marine sediments of very young geologic age, (3) lead in 6 marine limestones ranging in age from Precambrian to Pleistocene, and (4) lead in a very young plateau basalt. The data on lead in meteorites are regarded as the most significant contribution to the isotope geology of lead since Nier's pioneering analyses in 1938. As early as 1948 attempts were made to isolate lead from meteorites to ascertain isotopic compositions, but five years passed before success was attained. The meteoritic lead was found to be different from every terrestrial lead that has so far been tested: the meteoritic lead contains far less of the radiogenic isotopes than even the most primitive terrestrial lead known. The results suggest that if the earth is about 4.5 billion years old, it may have originally contained lead of such composition. The most fundamental question of all the problems of isotope geology of lead may now be near solution, i.e. what was the original composition of lead in the earth? In October, plans were made to try to demonstrate experimentally whether original earth-lead was similar to Patterson's meteorite-lead. In this experiment, primitive types of earth-lead will be sought for: (1) in rocks and minerals from the oldest known terranes of the Precambrian shields, starting with a suite of sample materials from Southern Rhodesia furnished by Dr. A. M. MacGregor, and (2) among those varieties of rocks that may perchance represent samples from deep within the earth.

One phase of this plan, a survey of very old Precambrian lead minerals, is in progress. The most interesting results to date have been obtained from primitive types of lead in a galena from Wyoming and in a suite of 7 galenas, all believed to be over 2 billion years old, from Southern Rhodesia. Three or four of the galenas appear to contain more primitive lead than any yet known from the northern and western hemispheres, but none appears quite so primitive as a galena from the Transvaal. The highlights of current knowledge on isotopic composition of primitive types of lead are summarized below in terms of the sum of the abundances of the 4 isotopes when Pb^{204} is taken as 1.0:

49.84 Most primitive Pb yet known: Canyon Diablo troilite, (Patterson, CIT)
60.70 Most primitive earth-Pb yet known: Transvaal galena, (Collins, et al, Toronto)
61.36 Most primitive earth samples so far: So. Rhodesian galena, (Cannon, USGS, Oak Ridge)
62.8 Most primitive earth-Pb outside Africa: Wyoming galena, (Cannon, USGS, Oak Ridge)
64.77 Most primitive earth-Pb known prior to 1951: Ivigtut galena, (Nier, U. of Minn., Harvard)

The following "young" types of lead are listed for better perspective:

72.65 Quaternary basalt, Idaho, (Patterson, CIT)
74.63 Recent deep sea sediment, Pacific Ocean, (Patterson, CIT)
75.28 Pleistocene limestone, California, (Patterson, CIT)

Information has been obtained on variations within single grains of galena. For each of two very old galenas, one from Southern Rhodesia and one from Ivigtut, Greenland, the center and perimeter of a single grain were sampled separately. Neither case seems to show variations like those found previously in a crystal of galena from Joplin. Etching tests failed to reveal evidence of any growth phenomena like the concentric growth layers found in the Joplin crystal, and isotope analyses do not show zonal variations like the Joplin crystal which exhibited maximum Pb^{204}-content and most primitive isotopic composition toward the growth-center.

Crystallography of uranium and associated minerals
by H. T. Evans

Montroseite and paramontroseite

A detailed structural analysis of the alteration product of montroseite (which has previously been shown to be VO(OH), the vanadium analog of diaspore), has revealed the mechanism of alteration of this ore mineral under weathering processes. The alteration product, with composition VO_2, which is now called "paramontroseite", has a structure similar to montroseite, but shows a considerable displacement of the atoms from the positions they have in montroseite. The most striking change is the increase of the hydrogen bond distance (oxygen to oxygen) of 2.72 Å in montroseite to 3.89 Å in paramontroseite. From these discoveries it is concluded that hydrogen is lost from the montroseite structure by migration through the undisturbed hexagonal close-packed oxygen framework, to reach the surrounding weathering medium.

Vanadium crystal chemical studies

The crystal structure of KVO_3 has been worked out in detail. It contains a chain consisting of VO_4 tetrahedra linked by corners in a zig-zag manner. This chain stands in marked contrast to that which has been found in $KVO_3.H_2O$. A least-squares and three-dimensional study has been made on the latter structure, and the 5-coordinated chain structure is now well established for this substance. These two structures raise many questions concerning the chemistry of the metavanadates, since both crystallize simultaneously from the same solutions (pH 7 to 8).

Uranium minerals

A comprehensive study is now in progress on the carnotite and autunite group of minerals. Of particular interest is the behavior of these layer structures to hydration and dehydration and base exchange influences. Much data have been gathered but it is too early to give a clear interpretation of the results. Other minerals under study are curite and schoepite, which represent the start of a program of study on uranium oxide hydrates. In cooperation with members of the Weathering Transportation and Deposition of Uranium Minerals Project, three weeks were spent in July and August in Paradox Valley, Colorado. A great deal of valuable information was gained concerning the association of minerals and their distribution in depth; in particular, it was found that montroseite may be the primary ore mineral. A large group of specimens were collected and sent back for crystallographic study in the laboratory.

In November, a member of the project group visited Dr. W. H. Barnes of the National Research Council (Ottawa) and Dr. C. P. Fenimore of The General Electric Research Co. (Schenectady), both of whom are studying vanadate crystal structures.

Up to this time the main effort of the project has been concentrated on the structural mineralogy of vanadium as applied to the Colorado Plateaus carnotite ore fields. It is planned in addition to build up more structure studies on the uranium minerals, especially the oxides and hydrates.

Papers and publications

Papers given at the American Crystallographic Association meeting at Ann Arbor, Michigan in June:

H. T. Evans and S. Block, "The crystal structure of montroseite."

C. L. Christ, J. R. Clark, and H. T. Evans, "The crystal structure of $KVO_3.H_2O$."

G. Donnay, "The 'polycrystal', a product of syntaxic intergrowth."

Papers given at the Mineralogical Society of America meeting at Toronto in November:

H. T. Evans and S. Block, "The crystal structure of KVO_3."

H. T. Evans and M. E. Mrose, "Alteration processes in montroseite."

G. Donnay and J. D. H. Donnay, "Tyuyamunite, carnotite and sengierite."

Papers in print:

C. L. Christ, J. R. Clark, and H. T. Evans, "The crystal structure of $KVO_3.H_2O$," J. Chem. Phys. 21, 1114 (1953) (preliminary note).

G. Donnay, "Roentgenite, $3CeFCO_3.2CaCO_3$, a new mineral from Greenland," Am. Min. 38, 868-870 (1953).

H. W. Jaffe, R. Meyrowitz, and H. T. Evans, "Sahamalite, a new rare earth carbonate mineral," Am. Min. 38, 741-760 (1953).

H. T. Evans and S. Block, "The crystal structure of montroseite," Am. Min. 38, (Nov-Dec., 1953).

G. Donnay and J. D. H. Donnay, "Crystallography of bastnaesite, parisite, roentgenite and synchisite," Am. Min. 38, (Nov-Dec., 1953).

Radon and helium studies
by G. B. Gott

Investigations relative to the origin and distribution of the radon, helium, and their parent radioactive elements in the western Panhandle field of Texas were continued during the past six months.

During this period the radon content of gases was measured in 355 natural gas fields in Kansas, Oklahoma, Texas, and New Mexico. In general, the radon content of these gases is much lower than it is in the Panhandle field. Betty Skipp made these measurements and her principal conclusions were as follows:

(1) There seems to be a general correlation between the radon content of gases and the proximity of the basement complex in anticlinal structures.

(2) Old wells and low pressure wells produce gases with the highest radon content.

Microscopic examination of drill cuttings shows that nearly all the wells in the northern and eastern part of the area under investigation contain black lustrous uraniferous asphaltite pellets in anhydrite and dolomite, interstitial asphaltite in siltstone, and dolomite and limestone with asphalt coatings and fillings. Asphaltite submitted for semi-quantitative analysis contains appreciable uranium and significant traces of arsenic, cobalt, yttrium, and bismuth. A quantitative spectrographic analysis of one pellet showed the uranium to run as high as 10 percent or more. Drill cuttings from the Kreiger #3 well in Kiowa County, Oklahoma, were examined and found to contain several hundred feet of black shale, which a qualitative fluorescence test indicated to be uraniferous. An asphaltite pellet from this well contained an estimated 20 percent uraninite.

A statistical study, based on spectrographic and chemical data, was made of the trace metal content of 25 different crude oils and 28 different asphaltites. Their distribution was plotted on graphs to show the relationship of the trace metal suite of the asphaltites to that of the crude oils.

Cooperative work carried out with the U. S. Bureau of Mines Experimental Station at Bartlesville, Oklahoma, indicates that adsorption of oil-water interfaces of organo-metallic complexes and micelles will concentrate the trace metals of petroleum into a lustrous black substance resembling the natural metalliferous asphaltites in physical appearance, in trace metal composition, and in lack of solubility with respect to organic reagents.

A filtrate from one crude oil from the Panhandle field contains minute particles of a highly lustrous insoluble substance resembling the natural asphaltites. A filtrate of uraniferous oil from a seep near Morrison, Colorado, also contained similar particles.

The data obtained during the past several months lead to the conclusion that the source of the radon in the Panhandle field is the uraniferous asphaltite pellets and impregnations in the reservoir and adjacent rocks. The uranium content of 28 samples of this material ranges between 0.1 and 10.0 percent uranium and it has been shown by an examination of drill cuttings that the radon anomalies are co-extensive with the uraniferous asphaltite.

The genesis of the uraniferous asphaltite is important to an understanding of the geochemistry of this type of deposit. The information now available indicates that the uraniferous asphaltite is a residual petroleum that was formed in place. The following evidence demonstrates this conclusion most convincingly:

(1) The uraniferous asphaltite is found in both marine and non-marine rocks. Hence it is not of syngenetic origin.

(2) Some of the asphaltite has replaced the surrounding calcite crystals and microfossils. Hence it is not of detrital origin.

(3) The asphaltite occurs in pore-spaces which are frequently oil-stained. Hence it formed from a fluid which permeated the rock pores.

(4) Nuclear emulsion exposures show that the uranium is uniformly distributed throughout the asphaltite. Hence the uranium was probably present in the organic matrix while it was in a fluid state.

(5) The trace metal suite found in the asphaltite is the same as that found in petroleum in nearby oil pools and the majority of the trace elements present in the petroleum are concentrated in the asphaltite by a factor of 104.

MINERALOGIC AND PETROGRAPHIC SERVICES AND RESEARCH

Services

Mineralogic studies, Washington
by Edward J. Dwornik

The Mineralogical Services Project-Washington consists of:

1. The Public Sample Program which analyses samples obtained from the public for radioactivity and,

2. The Special Sample Program which consists of mineral services performed for field geologists engaged in radioactivity reconnaissance for the AEC.

Under the Public Sample Program approximately 350 samples submitted from the public have been analyzed. Special mineralogic and petrologic study has been given to samples which have a radioactivity equivalent to 0.005 percent uranium or higher (about 20 percent of the samples). Detailed analyses were made of a group of 38 samples from foreign localities, which were submitted through the AEC office in Washington. Fifteen reports on mineralogic, petrologic and petrographic analyses, size analysis, and grain counts were prepared at the request of field geologists.

Analysis of a sample of apatite, with unusual properties submitted from Essex County, New York has been initiated. A report on the occurrence of this apatite that contains a high percentage of cerium and yttrium rare earths, will be prepared jointly with the submitter.

Approximately 1500 samples have been analyzed for and reported to geologists of the Southeast Monazite Project since June 1953. Sixty-one of 70 samples have been analyzed mineralogically for the Monazite Project.

Xenotime and monazite have been concentrated from several samples for age determination study. A report concerning the laboratory phase of this project is being written.

Approximately 1000 samples from the mineral collection of the National Museum have been examined with the aid of a scintillometer for significant radioactivity, i.e., when eU is 0.01 percent or higher. To date, 44 samples have been selected for further radioactivity, chemical, and mineralogical analyses.

Mineralogic studies, Denver
by L. B. Riley

During the report period 60 samples were identified as to mineralogic composition, and 212 by X-ray. The greater majority were received from the reconnaissance groups or directly from the A.E.C. office in Denver.

A summary report will be submitted before the end of fiscal year 1954 on the mineralogy of the Monument No. 2 mine, where two field seasons of mapping have been completed. In addition, field work on uranium mineralogy and on distribution of heavy metals has been supporting field projects in South Dakota. Preliminary studies indicate that there is correlation between various types of heavy metals in surface samples and uranium deposits, although further work will be necessary to substantiate the relationships.

A punched card technique for the sorting of X-ray patterns has been developed and promises to save much time in the identification of unknowns.

During the next report period the rate of X-ray and mineralogic identification probably will increase as the new facilities of the laboratory come into operation. A considerable part of the time of the project has been spent in assembling and calibrating new equipment.

X-ray
by C. L. Christ

As this is a service project, the report consists essentially of a list of the number of requisitions fulfilled. In addition, brief references to several problems of a more lengthy nature investigated by the personnel of the project, in collaboration with others, are given.

Samples and services:

Number of requisitions:	212
Number of samples:	531
Number of determinations:	747
Number of outside samples:	248

Of the samples originating outside the Geological Survey (outside samples in the list above), approximately one-half came from the New York office of AEC.

An X-ray study of radiation damage undergone by zircons on bombardment of α -particles has been made in collaboration with members of the radiation laboratory; and in collaboration with the Phosphate Project group, the lattice constants of carbonate apatites as a function of composition have been measured.

Electron microscopy
by Edward J. Dwornik

The facilities of the electron microscope laboratory during this report period have been devoted to supporting investigations in connection with laboratory studies of phosphorites; carbonaceous material; shales; uranium, vanadium, and associated clay minerals of the Colorado Plateau; and products of mineral synthesis. In addition, routine micrographing of clay and other fine grained minerals for reference purposes has continued. A total of 910 micrographs of approximately 103 different materials were added to the reference library.

Examination of phosphorite fines and mineral separates therefrom has proved helpful in corroborating X-ray, spectrometer, and petrographic identification of associated clay and phosphate minerals. These cooperative studies have confirmed the presence of hectorite in the deposits and also sedimentary apatite crystals, probably of secondary origin, in phosphatized clay zones. A report covering the application of the electron microscope to phosphate studies is in progress.

In conjunction with shale studies, particle size determinations have been made of mineral separates obtained by flotation, ball mill, and air elutriation methods. Work is continuing with the electron microscope and diffraction examination of carbonaceous pelletal and "woody" material.

Preliminary study of samples of unmineralized and mineralized hydromicas associated with Colorado Plateau vanadium ores suggests a mixture of at least 2 mineral phases.

Electron diffraction patterns obtained from the mineralized material show additional spacings not yet identified. The sample preparation procedure is being modified in an effort to concentrate separate phases and to reproduce identifiable electron diffraction patterns. Supplemental data obtained on those samples that have already been analyzed chemically, by X-ray diffraction, and for base exchange capacity may contribute to a better understanding of vanadium mineralization.

TEM-471, "Application of the electron microscope to mineralogic studies," has been revised for publication in the American Mineralogist.

Research

Research on techniques in mineralogy and petrology
by Edward J. Dwornik

The work of the project consists of (1) an investigation and correlation of the physical properties of minerals, (2) a review of the literature pertaining to mineral dressing and separation and, (3) the establishment of a bibliographic card file for this information.

Laboratory tests were made of two possible methods of separating heavy minerals of sp. gr. $>$ 3.3; e.g. galena from uraninite for age determination studies using the Pb isotope method. The tests were made on a simple laboratory separator embodying the principles of the Humphreys Spiral and the Cyclone Classifier. In these tests, an attempt was made to separate quartz from magnetite in water and in so doing observe the operation of the separator and the degree of separation obtained. Some separation was observed but the results thus far are inconclusive.

It has been suggested that a review of the magnetic properties of minerals at extremely low temperatures (-170°C) be made to determine if a possible magnetic separation of normally non-magnetic minerals would be feasible at these temperatures. A preliminary test was made to determine if the Frantz Isodynamic Separator could be adapted for low temperature work. The necessary changes in the machine, however, so reduced the intensity of the magnetic field that it was not possible to separate moderately magnetic minerals.

A paper entitled, "A multiple cone splitter for rapid sampling in the laboratory," by R. C. Kellagher (TEI-371), was written as the result of previous experimental work.

Technical assistance was also provided the project on distribution of uranium in igneous rocks. The problem was that of grinding 106 samples of granitic rock (approximately 2 tons) fine enough to free the mineral constituents without breaking the individual grains. Modifications of the crushing and grinding process were made and included; (1) construction of a steel bottomed box in which the rocks were broken to crushing size, (2) a device added to the crusher which held a 100 pound capacity canvas bag into which crushed rock fell directly and, (3) the construction of a large capacity aluminum screen for rapid sieving of the crushed material.

Properties of uranium minerals
by John C. Rabbitt

Work progressed on the monograph, "Mineralogy of uranium," being prepared under the editorship of Rabbitt. Clifford Frondel of Harvard University, who has a W.A.E. appointment with the Geological Survey, is responsible for the chapter on description of properties; Judith Frondel, who also has a Survey W.A.E. appointment, is preparing descriptive tables; George Switzer of the U. S. National Museum is writing chapters on the occurrence and association and the geographic location of the minerals; Theodore Botinelly of the Survey is writing a chapter on characteristic methods of identifying uranium minerals in the field and laboratory. The several chapters are in different stages of preparation. The chapter on properties was turned into the editor in draft form in July and is now being critically reviewed by Alice Weeks. Clifford Frondel has been in Vienna since July and reports that he has unearthed some European data that can be included in the monograph.

During this period chemical analytical work was completed on pure samples of diderichite, schoepite from Beryl Mountain, New Hampshire, and a possible new distinct phase referred to as green "uraninite". This last mineral contains 71.6 percent UO_3, 2.8 percent UO_2, 5.6 percent ThO_z, 4.9 percent PbO, and 7.7 percent H_2O as major constituents.

In addition, spectrographic analyses were completed on a group of problem minerals that occur as alteration rims around uraninite. Five of these are now undergoing complete chemical analysis and the results should be ready for inclusion in the monograph in January 1954.

No additional work by Judith Frondel (on the hydrous uranium oxides) nor by Clifford Frondel was done because of their absence in Europe.

During the six-month period two reports, previously issued as U. S. Geological Survey TEI reports were published in the American Mineralogist:

1. Studies of uranium minerals: The status of billietite and becquerelite, by Judith W. Frondel and Frank Cuttitta.

2. Hydroxyl substitution in thorite and zircon, by Clifford Frondel.

In addition, one TEI report was issued:

Studies of uranium minerals: An alteration product of ianthinite, by Judith W. Frondel and Frank Cuttitta, U. S. Geological Survey TEI-367, August 1953.

GEOPHYSICAL PROSPECTING SERVICES AND RESEARCH ON METHODS

Development and maintenance of radiation detection equipment

by W. W. Vaughn

The activities of the Instrument Group center around the following objectives:

1) The maintenance and calibration of radiometric equipment used by the USGS and the AEC.

2) Research and development of special equipment as time permits.

3) Fabricating and installing equipment for special applications.

4) Modifying existing equipment for better control of data.

5) Contracting for and field testing of new instruments.

The need for maintenance and calibration of portable radiometric equipment used by the USGS and the AEC is now greater than ever before. The increase is primarily due to the 140 scintillation counters of the USGS that were put in the field this season, and approximately 25 counters belonging to the AEC which were serviced from this laboratory.

A prototype model of a new portable scintillation counter was designed and built. It is a total intensity type meter, weighs 3.5 lbs., has a displacement volume of 71.5 cubic inches and a battery life of 180 hours. As the name implies, the meter reading is proportional to the integral of the light output from the NaI crystal within limits, the lower limit being the dark current of the phototube, and the upper limit the saturation point of the scintillation head.

An instrument for studying thermoluminescence of rocks was designed and partially constructed. This unit consists of a temperature controlled oven, phototube, amplifiers and recorder; and a high voltage supply. The lack of knowledge as to the application and practical operation of this instrument has hindered its completion. There is some doubt whether or not the sample observed will emit sufficient light to drive the Brown recorder, through the media of phototube and amplifier, as a standard unit. Also, the control of temperature versus time for the proper temperature-time versus luminescence will be solved on a trial and error basis.

Installation of a large area (8" x 8") alpha scintillation counter for radiation assaying of low-level materials and of a two-inch proportional alpha-beta counter for the study of non-equilibrium materials has been completed in cooperation with the Denver Trace Elements Laboratory. The scintillation counter constructed in our laboratory is modified after the Harwell design.

A test system for checking photomultiplier tubes in rapid fashion has been designed and constructed. The system consists of a light-tight compartment containing a removable crystal and an adjustable phototube holder which permits the phototube under test to be vibrated while the electrical characteristics are being evaluated. The British E. K. Cole ratemeter type 1037A is used for counting and recording purposes because of its excellent stability. Better selection of phototubes, which is of prime importance in the maintenance of scintillation counters, can be made in this manner.

Original plans called for construction of eight portable carborne scintillation counters and eight portable gamma ray logging reels for the past field season. Four of the reels have scintillation probes and four have Geiger tube probes. To date, five of the logging reels and four of the carborne units have been completed.

The most used photomultiplier tube, RCA 6199, which has been reported to have a factor of 17 difference in sensitivity characteristics under fixed dynode voltage, shows more uniform operation when individual phototubes are provided with their optimum operating voltage. The Victoreen Instrument Company has agreed to supply voltage regulator tubes ranging from 850 to 1150 volts.

Considerable experimentation with germanium transistors show the temperature coefficient to be greater than can be tolerated in our equipment for the field without excessive compensation. However, some promising results have been obtained. Silicon transistors, when available, may be more useful in this respect.

Some field work of the past season has indicated that readings with a portable scintillation counter of .004 mr/hr are significant in formulating an isorad chart for delineating favorable zones for occurrence of uranium.

We plan to contract for the following major items this winter:

10 - Portable scintillation logging units (with recorders).
10 - Carborne scintillation counters (with recorders).
30 - Portable hand scintillation counters.

Airborne radioactivity surveying
by R. M. Moxham

As scintillation detection equipment has now been developed to the point where reproducibility and reliability are entirely satisfactory, a series of experimental measurements to determine the optimum conditions of measurement and to calibrate the response of the equipment in relatively quantitative units were planned and undertaken in cooperation with the Oak Ridge National Laboratory.

At Cherokee Reservoir, Granger County, Tennessee, a series of measurements ranging from 1000 to 100 feet over four point sources - Cs^{137}, Co^{60}, Au^{198}, and Ra - were made to determine the nature of gamma-ray scattering and absorption from point sources of various energy level. The reduction of data is in progress.

To complete calibration of airborne equipment, two basic geometric source configurations were required, a point source and a semi-infinite plane source. To simulate insofar as possible a "point" source such as might occur in nature, 47 tons of .35 percent U_3O_8 carnotite ore from Grants, New Mexico was emplaced at Walker Field, Grand Junction, Colorado in the form of a slab 40 feet square by 6 inches thick. As a semi-infinite plane source, a flat mesa top northwest of Fruita, Colorado was selected.

Measurements at various energy levels were made from 100 to 1,000 feet over both types of source configuration. Similar measurements were made at various distances (horizontal) from the point source in order to determine empirically an equation for integrating the point source radiation intensity. The foregoing measurements were repeated with several geometric arrangements of lead shielding to determine whether any increase of sensitivity might be thus attained.

Although these measurements have not been fully evaluated, it appears that the maximum sensitivity is attained by operating the equipment unshielded, and in such a manner as to accept the lowest possible energy levels, i.e., on the order of 40 kev. The overall effect of shielding was to decrease, rather than increase sensitivity. It may also be possible to estimate, from the airborne radioactivity anomalies, grade-area values of uranium-bearing source materials. If the source material is of sufficient extent for the boundaries to be delineated by the airborne surveys, the grade of the source area may be estimated.

Airborne radioactivity surveys were resumed upon completion of the calibration tests. The Browns Park and adjacent formations in Sweetwater and Carbon counties, Wyoming were surveyed (fig. 46). A total of 3750 traverse miles were flown:

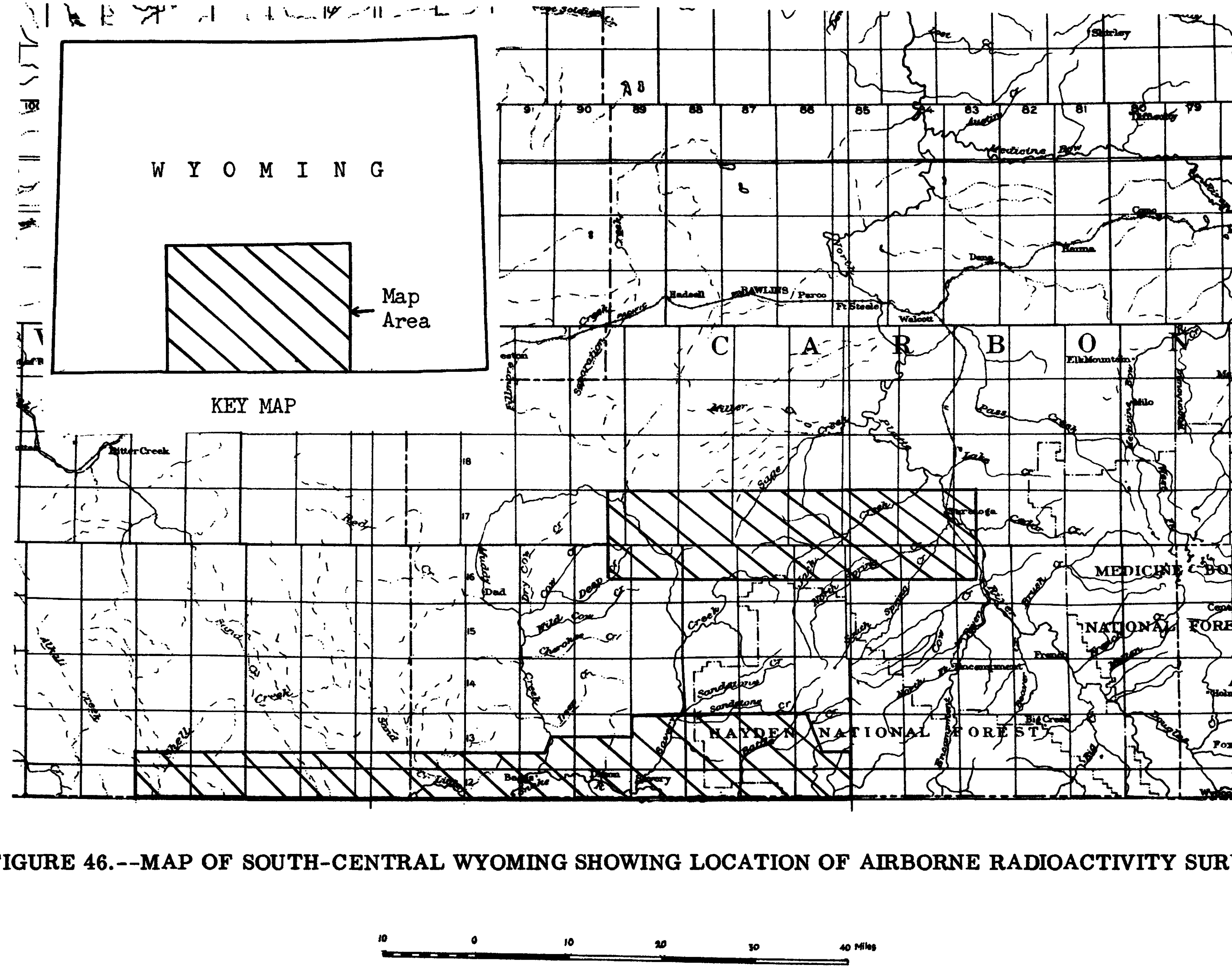


FIGURE 46.--MAP OF SOUTH-CENTRAL WYOMING SHOWING LOCATION OF AIRBORNE RADIOACTIVITY SURVEY

State	County	Traverse Miles
Wyoming	Sweetwater	310
	Carbon	3,440

Significant abnormal radioactivity was detected at many localities, situated in the following areas:

NE$\frac{1}{4}$ R92W, T12N	NE$\frac{1}{4}$ R86W, T16N	W$\frac{1}{2}$ R86W, T17N
SE$\frac{1}{4}$ R92W, T13N	R85W, T16N	S$\frac{1}{2}$ R87W, T17N
NE$\frac{1}{4}$ R89W, T16N	W$\frac{1}{2}$ R84W, T16N	NE$\frac{1}{4}$ R89W, T17N
E$\frac{1}{2}$ R88W, T16N	R84W, T17N	

Two of the radioactive anomalies, in Secs. 4 and 5, T12N, R92W, were investigated on the ground, and carnotite (?)-bearing sandstone was found. At least some of the material appears to be of ore grade.

The radiation intensity recorded in several of the areas listed above appears to be quite significant. The airborne survey data have been transmitted to field parties for ground investigation. A report giving the results of the airborne surveys is in preparation.

During the last half of fiscal year 1954, it is anticipated that airborne radioactivity surveys will be undertaken as follows (fig. 47):

State	Counties	Areas	Map No. (fig. 47)
Arizona	Apache	Defiance Uplift	1
	Mojave	Arizona Strip	2
	Coconino		
Colorado	Moffat	North Craig	3
Florida	Hardee	Phosphate	4
	Manatee		
	Charlotte	Phosphate	5
	Lee		
	Baker	Trail Ridge	6
	Bradford		
	Clay		
	Alachua		
	Putnam		

Fig. 47--Airborne Radioactivity Survey Projects.

(See page 285.)

State	Counties	Areas	Map No. (fig.)
Georgia	Thomas Brooks	Phosphate	7
	Toomes Tuttnal Appling Wayne Long Macintosh Glynn Brantley	Phosphate	8
Montana	Blaine	North Bear Paw	9
Pennsylvania	Monroe Carbon	Mauch Chunk	10
South Carolina	Berkeley Dorchester Charleston	Phosphate	11
South Dakota	Pennington Custer	Black Hills	12
Utah	Duchesne Uintah	Myton	13
Wyoming	Converse Goshen Niobrara Weston	Pine Ridge escarpment Hartville-Newcastle	14 15

Physical behavior of radon

by A. S. Rogers

A detailed investigation of radon distribution in surface streams was undertaken in three small areas in the Central Wasatch Mountains, adjacent to Salt Lake City, Utah. The streams flow over an almost complete stratigraphic sequence from Upper Cretaceous through Cambrian.

No precipitation occurred during the sampling periods and repeat samples taken over a period of three months generally show little variation in radon content of stream water. The amount of radium in solution (about 2×10^{-12} grams per liter) is negligible compared to the radon content which varies through several orders of magnitude. A scintillation and Geiger counter survey showed no unusual radioactivity within the drainage areas of the streams investigated. The middle phosphatic shale member of the Park City formation may be slightly uraniferous, as one selected sample contained 0.003 percent eU.

Based on the observed radon distribution, the following conculsions are presented:

1. High radon concentrations in stream water are related to surface springs and also to lithologic changes in the stream channels. Sudden increases of radon content are caused by the entrance of ground water into stream channels, although in most places there is no visible evidence of spring activity.

2. Radon is rapidly flushed from stream water into the atmosphere, probably within 500 to 1,000 feet downstream from point of entry. Laboratory studies show that exposing radon-bearing water to air by pouring and measuring volumes releases about 50 percent of the radon to the atmosphere. It is important that a sampling method be used in which the sample is never exposed to air once it has been taken.

3. High radon content in stream water can in some places be related to a particular stratigraphic formation.

4. A stream flowing on or near bedrock shows higher and more abrupt changes in radon content than one which is choked with cobbles, gravel and other debris.

The measurement of radon in streams may be of value as a tool in uranium exploration. As no known abnormal uranium concentration exists in the areas investigated, with the exception of the slightly radioactive phosphatic member of the Park City formation, the magnitude of the radon concentrations here reported establishes a normal or "background" level for stream water. The method may also be useful in ground water studies as high radon concentrations mark the entrance of ground water into the streams.

More measurements of radon in stream waters will be made periodically through the winter and spring to note the effects of precipitation and run-off in watersheds. A comprehensive report covering this phase of the investigation will then be written.

Absorption and scattering of gamma radiation

by Arthur Y. Sakakura

Experimental

Cylindrical geometry experiments (simulated drill holes)

Examination of data taken at the National Bureau of Standards (point radium source in an infinite medium surround a cylindrical cavity) revealed the necessity of making more accurate measurements before the integration of data over various configurations will yield reliable results on the effect of cavity sizes and source thicknesses on the counting rate. To this end, a quenching circuit was built by the laboratory which allows the use of the counter at higher counting rates. The experimental work will start in December, 1953.

Plane geometry (air-borne radioactivity survey)

Measurements were made on point sources of Cs^{137}, Co^{60}, Au^{198}, and Ra at the Oak Ridge National Laboratory.

Measurements were made in Grand Junction over simulated sources of uranium ore and over general background so that an absolute calibration of the equipment could be made, as well as to obtain data on scattering of radiation in plane geometry. Tentative results to date are:

(1) The general background showed (within limits of error) a pure exponential decay with absorption coefficient, u of 1.83×10^{-3} ft.$^{-1}$ at Grand Junction or 2.93×10^{-3} ft.$^{-1}$ at sea level. This is an effective absorption coefficient, and no significance should be attached to any concept of effective energy.

(2) Point source reveals a behavior of the form

$$C \frac{e^{-\mu r}}{r^s} \left(\frac{z}{r}\right)$$

where

C - constant - $(1.08 \pm .02) \times 10^6$
s - $1.28 \pm .05$
r - total distance from center of source in feet
z - altitude in feet

The factor $\frac{z}{r}$ is merely a geometry factor for the effective area of the source "seen" by the instrument. This behavior applies only to distances greater than 500 feet, the lesser distances show markedly different behavior.

(3) Arbitrary sources can be represented by:

$$\frac{\sigma}{\sigma_o} \frac{C}{A_o} z \int_A dA \frac{e^{-\mu r}}{r^{1+s}}$$

where

σ_o - source density of the Grand Junction source
σ - source density of the arbitrary source
A_o - Area of the Grand Junction source

integration being performed over the source area.

The above indicated operation will be performed over various source configurations in order that suitable interpretation of actual reconnaissance can be made.

Theoretical

The two media problem, in principal, has been solved. Only a recapitulation of the method will be given here. Two sided Laplace transform of the transport equation is performed over the space variable, the boundary values being replaced by the transformed gamma-ray density at certain values of the transform parameter in their respective domains of analyticity. The resulting pair of integral equations are solved by constructing a Lagrangian interpolation polynomial for the angle and Laplace transform variables. The integration over the energy is performed by mechanical quadrature. The resulting system of linear algebraic equations is to be solved on a digital computer. Then an analytical function can be constructed and finally inverted to yield the total gamma ray density.

The main obstacle is the solution of the algebraic equations, as it will take an army of mathematicians with finite lifetimes to solve them. To this end, a visit to the N. Y. U. digital computer is scheduled to see whether the project is feasible.

Gamma-ray logging

by K. G. Bell

During the past six months, several modifications of the electronic design of the gamma-ray logging instrument have been made to improve the stability and response to high intensity radiation such as encountered in ore zones. These modifications necessitate recalibration of the instrument in terms of thickness and equivalent uranium content; the recalibration should be completed early in 1954.

Measurements of the variation in diameter of 5 drill holes in the Jo Dandy area were made by the U. S. Bureau of Mines using a truck-mounted caliper logging device designed by the Petroleum Experiment Station at Bartlesville, Oklahoma. Data on the expectable variation in drill holes will aid in the interpretation of gamma-ray logs.

RESOURCE STUDIES

by A. P. Butler, Jr., J. C. Olson, G. W. Walker, and George Phair

The Survey's general studies of resources of radioactive raw materials were transferred from Washington, D. C., to Denver, Colorado, on May 30, 1953. When the Resources Group is complete, it will consist of full or part-time specialists in the fields of sandstone deposits, vein deposits, lignites, shales, phosphates, miscellaneous sediments and hydrocarbons, igneous rocks, thorium, natural waters, geochemistry, and natural radioactivity of rocks. Staff members specializing in uraniferous veins, igneous rocks, phosphates, and thorium, and most of the supporting technical and clerical staff were assembled before December 1.

Work during the reporting period consisted mainly in establishing, reorganizing, and indexing file information in Denver and preparing resource data cards of localities examined by USGS and AEC personnel. Localities and grade are plotted currently on work maps. To date, information on about 4,000 localities has been abstracted and distributed. The backlog of information to be abstracted has been reduced to about one month.

Review of published and unpublished data in the files of the USGS pertaining to domestic uraniferous vein deposits and related foreign deposits has been started. Assembly of all available information on domestic thorium deposits has been carried on as a part-time activity leading to a compilation of data on geology and resources of thorium and will be continued during the remainder of fiscal year 1954. Research into the radioactivity of igneous rocks has consisted of study and selection of methods for organizing pertinent information collected by the several Survey projects relating to the subject. Analysis and interpretation of the data will be directed toward determining the geological and geochemical controls governing the fractionation of radioactive materials in magmas and hydrothermal solutions, the distribution of radioactive igneous rocks in the United States and elsewhere, and the relation between radioactive igneous rocks and uranium deposits.