

(20)  
T67r  
no. 280

UNITED STATES GEOLOGICAL SURVEY

TEI-280

TRACE ELEMENTS RESEARCH  
QUARTERLY PROGRESS REPORT —  
APRIL 1 TO JUNE 30, 1952

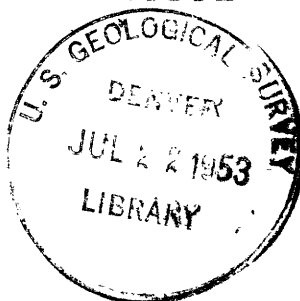
This preliminary report is released without editorial and technical review for conformity with official standards and nomenclature, to make the information available to interested organizations and to stimulate the search for uranium deposits.

March 1953  
[TIS Issuance Date]



Prepared by the Geological Survey for the  
UNITED STATES ATOMIC ENERGY COMMISSION  
Technical Information Service, Oak Ridge, Tennessee

20864



## GEOLOGY AND MINERALOGY

In the interest of economy, this report has been reproduced direct from copy as submitted to the Technical Information Service. Since nontechnical and nonessential prefatory material has been deleted, the first page of the report is page 5.

TRACE ELEMENTS RESEARCH QUARTERLY  
PROGRESS REPORT\*

April 1 to June 30, 1952

Trace Elements Investigations Report 280

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

## TRACE ELEMENTS RESEARCH QUARTERLY PROGRESS REPORT

April 1 to June 30, 1952

## ABSTRACT AND SUMMARY

## Colorado Plateau geologic studies

Two project teams of the geologic mapping program--the southwestern Colorado and the Carrizo Mountains project teams--continued map compilation and report preparation through the period of this report. Four mapping project teams--Monument Valley, Ariz.: Monument Valley, Utah (new project); White Canyon, Utah; and Capitol Reef, Utah--began their 1952 field season in early May. An interesting and possibly significant discovery of what appears to be a previously unknown mineralized area near Oljeto Trading Post, San Juan County, Utah, was reported from the Monument Valley, Utah, project. Some uranium mineralization is reported from the Monument Valley, Ariz., project on two mesas in Monument Valley, Navajo County, Ariz.; further investigations will be necessary for proper evaluation or possible recommendations for physical exploration of these areas.

During the quarter, by the stratigraphic-studies program it was determined that the Shinarump conglomerate of Late Triassic age in its type area is, as described by earlier geologists, fundamentally a basal conglomerate to the Chinle formation of Late Triassic age, rather than an ill-defined stratigraphic unit comprising several variable interstratified lithologies in the lower part of the Chinle formation.

In connection with the program of study of the structural history and igneous geology of the Colorado Plateau, it was determined that radioactive minerals are at least moderately abundant in the stock of the north La Sal Mountains. There is no evidence as yet to indicate whether or not the deposits are of economic interest, but they are being studied intensively to learn the behavior of radioactive elements in magmatic solutions.

Ground-water studies were resumed in mid-June. Resource studies in the area between the Colorado and Green Rivers, Grand and Wayne Counties, Utah, indicate that uranium deposits are at the margins of lenses of the Shinarump conglomerate or in areas where the conglomerate for the most part passes laterally into siltstone and claystone.

Studies of X-ray patterns resulted in the discovery of a new, unnamed uranium mineral from samples collected in the Gateway and Paradox districts, Mesa and Montrose Counties, Colo., and Grand County, Utah.

## Phosphates

Northwest phosphate.--Areal geologic mapping was continued in two areas in Idaho and Montana; compilation of data and preparation of reports were continued for six other areas. Stratigraphic studies in northwestern Wyoming suggest that a previous hypothesis of correlation is not entirely satisfactory; the choice between several correlation hypotheses must await additional mapping and field work. In the phosphate-sampling program in Wyoming, several trenches were dug, measured, and sampled, and the southern part of the Wyoming Range was reconnoitered for possible trench sites. Preliminary results of field studies, in the absence of analyses, indicate the presence of five zones of phosphate within the Phosphoria formation of Permian age; of these, the lowermost zone is the richest in phosphate at the South Mountain pit, whereas the uppermost zone is the richest farther north.

Southeast phosphate.--Geologic work done in the quarter ending June 30, 1952, consisted of: 1) studies of the leached-zone distribution, which indicate that the drainages of the Peace and Alafia Rivers contain the thickest and highest-grade leached zone and that the divide between them contains thinner and lower-grade material; 2) studies of relations of  $P_2O_5$ ,  $Al_2O_3$ , and uranium, which indicate an increase in uranium content with an increase in  $P_2O_5$  and  $Al_2O_3$ ; 3) continuing studies of stratigraphy and origin, which indicate that the phosphate deposits may have several modes of origin--including a residuum of Miocene age, a reworked residuum of Pliocene age, a reworked residuum of Quaternary age, or most probably, a combination of all three.

Phosphate studies in the eastern Gulf of Mexico.--The results from a study of the collection of 1,178 bottom samples and 10 dredge hauls suggest that

the underlying phosphatic limestone and coquina are the source of the overlying unconsolidated phosphatic sediments in the Guld of Mexico adjacent to the Tarpon Springs-St. Petersburg and Venice-Englewood areas. Some phosphatic replacement of Foraminifera tests is suggested in the Tarpon Spring-St. Petersburg area.

Laboratory studies of all the samples that were collected will be continued.

### Analytical methods

Spectrography.---The Hilger spectrograph has been effectively used for the qualitative spectrographic analysis of single mineral grains, X-ray spindles, and other microsamples weighing 1 mg or less.

In the work on the adaptation of the Leeds and Northrup microphotometer to automatic scanning of spectrograms prepared in the semiquantitative method, the spectra of 69 elements in six concentrations have been scanned, and the analytical lines have been located and marked. Duplicate card catalogs were prepared containing information on wave length and height and width of the lines relative to the element concentration. A Gaertner spectrogram of 1 mg of R.U. powder was traced with the Leeds and Northrup instrument. The lines representing 14 elements were detected without difficulty, thus indicating the possibility of automatically scanning spectrograms prepared in the semiquantitative method with prism instruments as well as with grating instruments.

Chemistry.---A variety of organic compounds were investigated as possible reagents for use in the determination of thorium; after intensive study, morin was found to be unsuitable because the lower limit of detection instrumentally was too large, and the standard calibration curve was S-shaped.

In the investigation of the determination of micro amounts of  $P_2O_5$  in the presence of As, Si, and Ge, experimental work on Goal 1 was completed. Goal 1 was to establish optimum conditions for the determination of each element in the absence of the others by the molybdenum-blue method.

Experiments using the radioactive tracer  $Pb^{210}$  showed that lead could be concentrated from sea water by passing it through a synthetic cation exchange resin. Samples of calcareous sediments were examined spectrographically for lead and other trace elements. In none of the samples was the lead content high enough to allow separation of milligram quantities of lead iodide in a reasonably convenient manner. A notable concentration of lead was observed in one of several samples of manganese nodules collected from the bottom of the Pacific Ocean and also in the insoluble fraction of a rock-salt sample from Michigan.

## Geochemistry and petrology

Distribution of uranium in igneous complexes.--Data now in hand indicate that Idaho batholith rocks are very low in uranium; the California batholith rocks are higher; the lavas of the San Juan Mountains, Colo., are still higher; and the igneous rocks of Carboniferous age in New England are the highest of those studied. The high content of monazite and allanite in the Idaho rocks indicates that they are high in thorium.

Synthesis of uranium-bearing minerals.--Work on mineral synthesis at room temperature and normal atmospheric pressures resulted in definitely confirming two synthetics of the uranite group and synthesizing two additional members. Work began on the vanadates, and attempts were made to synthesize tyuyamunite, rauvite, and  $\text{FeVO}_4$ . Only the  $\text{FeVO}_4$  seems to have been made. Lack of an X-ray standard pattern prevents positive identification.

X-ray diffraction studies.--X-ray work on montroseite shows that the patterns give three sets of reflections corresponding to three distinct orthorhombic forms. These sets correspond to three phases in parallel (syntactic) intergrowth. The space group is Pbn. The unit cell must contain 8 oxygens. The formula will best be determined by crystal-structure study.

Work on the rare-earth carbonates in the parisite-synchisite series, using crystals of the parisite type from several localities, shows that the crystals consist mainly of intergrowths of at least five different hexagonal phases in parallel orientation. The prevalence of intergrowths in these crystals makes analytical data of questionable value. A few crystals have been isolated for chemical and optical measurement.

The possibly new rare-earth carbonate mineral provisionally named "sahamalite" by Howard Jaffe was studied, and the data will be reported when the study is complete.

Isotope geology.--Fourteen samples of uranium minerals were prepared and sent to J. J. Katz, Argonne National Laboratory, for quantitative oxygen determinations and  $\text{O}^{16}/\text{O}^{18}$  temperature studies. The samples are: eight pegmatitic uraninites; uraninite from the Happy Jack mine, Utah; two synthetic uraninites, and a synthetic fourmarierite prepared by Professor John Gruner, University of Minnesota; a very pure calcium uranyl vanadate (tyuyamunite) from the Small Spot mine, Colo.; and a specimen from La Sal No. 2 mine, Colo., of an unidentified uranium mineral. Also, two uraninite samples from the Colorado Plateau were prepared and sent to Professor Patrick Hurley, Massachusetts Institute of Technology, for helium determinations.

Chemical analyses were completed on carefully purified heavy-liquid separates of two possibly new minerals from La Sal No. 2 mine--one that has a tetragonal structure similar to zircon but contains mostly oxides of uranium, and another that contains vanadium.

Samples of 21 Colorado Plateau ores were prepared for age studies and submitted for chemical analysis and preparation of lead iodide. In addition,

samples of six galenas from the Plateau were prepared and submitted for analysis. Isotopic analyses of eight lead iodides were received from Oak Ridge.

### Mineralogy and petrography

Analytical work was completed on samples of curite, ianthinite, billietite, orange schoepite, kasolite, uranophane, cuprosklodowskite, soddyite, sklodowskite, and beta-uranotil. An abstract, "Billietite and becquerelite," was prepared by Judith Weiss Frondel for presentation at the Geological Society of America meeting in November. The abstract reports that billietite is a valid mineral species isostructural with becquerelite.

Results of a study by Clifford Frondel by X-ray and optical methods and, in part, by thermal analysis, indicate that thorogummite (including nicolayite), maitlandite, hyblite, and mackintoshite are identical. The X-ray patterns of these minerals can be completely indexed in terms of a tetragonal cell with the space group and virtually the same cell dimensions as thorite.

A second revised edition of "A glossary of uranium and thorium-bearing minerals," by Judith Weiss Frondel and Michael Fleischer, was published during the quarter as U. S. Geological Survey Circular 194.



## TRACE ELEMENTS RESEARCH QUARTERLY PROGRESS REPORT

April 1 to June 30, 1952

## SANDSTONE-TYPE DEPOSITS

Colorado Plateau geologic studiesIntroduction  
by L. C. Craig

The Colorado Plateau geologic studies comprise a number of regional-mapping and detailed geologic studies of the pre-Morrison (mainly Triassic) and Morrison ore-bearing formations. The principal objectives are to determine the distribution and character of the ore deposits and the host strata, to determine geologic relations that may be useful in guiding exploration, and to appraise the total resources of the Colorado Plateau region.

All the geologic-mapping program and most of the resource-appraisal program have been placed on a quarterly reporting basis. With the inclusion of these programs in this report, all but a few of the Colorado Plateau geologic studies will be on a quarterly reporting basis. This arrangement will not impede the rapid reporting of significant findings by members of these programs for such discoveries will be reported separately either in the regular monthly reports or as entirely separate memoranda. This arrangement should permit the presentation of tangible geologic progress from most of these long-range research programs with each quarterly report.

## Geologic mapping

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

The principal objectives of the regional geologic mapping project in southwestern Colorado are to determine the geographic and geologic distribution of the carnotite deposits, the broad geologic controls, and the

relations to regional stratigraphy and structure, as well as to delimit areas favorable for detailed studies and exploration.

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

Compilation on topographic base maps from air photos . . . . .	100%
Preparation of structure contour maps . . . . .	100%
Preparation of structural sections . . . . .	100%
Writing of texts to accompany geologic quadrangle maps . . . . .	20%
Editorial review and criticism . . . . .	10%

In addition work was begun on a paper for publication on the structural development of salt anticlines on the Colorado Plateau.

The project was recessed on June 20 and will be inactive until September 15, 1952, when preparation of texts will be resumed. It is anticipated that the project will terminate with the completion of these maps in fiscal-year 1953.

Carrizo Mountains project, by J. D. Strobell, Jr.

Geologic mapping of the Carrizo Mountains area, Apache County, Ariz., and San Juan County, N. Mex., was undertaken to provide detailed information on the geologic setting of carnotite deposits in the 30-minute quadrangle surrounding the Carrizo Mountains. The field mapping was completed September 1, 1951, except for the mountains themselves, and work during this quarter consisted of compiling a geologic map from the air photos used in the field. Preliminary drafts of this map, in units covering  $7\frac{1}{2}$ -minute quadrangles at 1:20,000 scale, were also prepared for advance transmittal to AEC, and seven of these quadrangles were distributed in June; the other nine will be distributed soon after July 1.

During the next quarter the map, accompanied by text and stratigraphic sections, will be prepared for publication at 1:48,000 by the Geological Survey, probably as one of the Oil and Gas Map series. The project will be recessed

from the fall of 1952 until the spring of 1953. The laccolithic complex of the Carrizo Mountains will be mapped in the field season of 1953 and a final report on the geology of the area and of the carnotite deposits will be prepared.

Monument Valley, Arizona, project, by I. J. Witkind

The Monument Valley areal mapping project, Apache and Navajo Counties, Ariz., has three principal objectives. They are to determine the distribution and character of the uranium-bearing strata, to study geologic relations that may be useful in guiding exploration and appraising the total resources, and to prepare a geologic map of the three quadrangles comprising the area of investigation.

During the 1951 field season about 75 percent of all the Shinarump conglomerate outcrops in the three quadrangles was studied. TEI-204, "Geologic and uranium investigations in the Monument Valley area, Arizona" by I. J. Witkind, D. H. Johnson, T. L. Finnell, and R. J. Claus, summarizing the results of this work, is in preparation. Outcrops of the Shinarump conglomerate in the Utah part of Monument Valley were recommended for study and a new project planned. During this report-quarter, most of the month of May was devoted to the training of the personnel comprising the Monument Valley, Utah, project. This party moved into Utah near the end of May. During June the major endeavor of the Monument Valley, Ariz., project has been to complete the areal mapping in those areas adjacent to outcrops of previously mapped Shinarump conglomerate.

By the end of the quarter geologic mapping has been completed for 70 percent of the three quadrangles. Structure contours have been extended across most of the mapped area.

Two mesas in Monument Valley, Navajo County, Ariz., were found to contain uranium minerals:

1) Hunts Mesa (Long.  $110^{\circ}03'$  W., Lat.  $36^{\circ}54'$  N.) has several channels showing moderate uranium mineralization. The Atomic Energy Commission has

prepared an R.M.O. report on the mesa, and at one time proposed a drilling program. This program has apparently been abandoned due to anticipated difficulties in building an access road. Details on this claim are in the above-mentioned R.M.O.

2) Mitchell Butte Mesa (Long.  $110^{\circ}06'$  W., Lat.  $36^{\circ}58'$  N.) exposes a channel that can be traced for about two miles. At one point the channel is intersected by a deep canyon and the base of the channel is clearly exposed. Along the base of the channel a seam of carnotite is present about four ft. long, and ranging in thickness from  $1/4$  in. to about  $1/2$  in. Locally the seam loses its continuity and forms small pod-like masses of carnotite in coarse-grained sandstone. It is suggested that a body of carnotite may be concealed in the channel and ground water percolation along the channel may be leaching the carnotite in one locality and redepositing it at the outcrop. If ore bodies are within the channel, they would probably be of small size, and irregularly distributed along the channel floor.

Further investigation of these areas of mineralized ground in the light of the overall knowledge of uranium deposits of the Monument Valley area will be necessary for proper evaluation and for any possible independent recommendations for physical exploration. It may be noted that both areas are inaccessible and the cost of road construction would be high.

Present plans call for the completion of field work in September 1952. At that time all of the outcrops of the Shinarump conglomerate in Monument Valley, Ariz., will have been examined and those areas suitable for physical exploration will be outlined, a revised list of ore guides will be prepared, and a geologic map of the area will be available which will include, as inherent components, isopach maps of the sedimentary formations and a structure contour map.

Plans have been outlined with the Survey's Geophysical Studies group for a resistivity study of several channels in the area. These plans have been discussed with J. W. Chester of GJEB, and supplement geophysical work carried on by that organization. In detail, the Geological Survey plans call for a study of the size and continuity of channels scoured in the Moenkopi formation and filled with Shinarump conglomerate. The Atomic Energy Commission's geophysical plans in this area, as expressed by Chester, call for a specific search for deeper scour pockets in the channel floors.

Monument Valley, Utah, project, by D. E. Trimble

The Monument Valley strip-mapping project, San Juan County, Utah, is planned to study the Shinarump conglomerate and, more particularly, the contact between the Shinarump conglomerate and the Moenkopi formation in the Monument Valley area bounded on the north by the San Juan River and on the south by the Arizona-Utah state line, to determine features which may relate to the origin or localization of uranium deposits in the Shinarump conglomerate, and to locate any deposits of uranium or areas suitable for exploration for hidden deposits.

The project was initiated in early May 1952. Most of May was spent in field conferences, mainly in the Arizona part of Monument Valley, to gain geologic background for the project. Field work on the assigned area began on May 26, 1952. During the ensuing five weeks of field work about one half (approximately 100 miles) of the accessible Shinarump conglomerate in the Utah part of Monument Valley has been traversed. The Shinarump-Moenkopi contact, except where inaccessible or obscured by talus, has been observed and has been tested for radioactivity with a Geiger counter.

As has been noted previously by many prospectors and field geologists in this area, the uranium mineralization seems to be confined to Shinarump-filled channels in the Moenkopi formation. A discovery of what is believed

to be a previously unknown mineralized area that may prove to be a substantial deposit of ore quality was made in the NW $\frac{1}{4}$ SE $\frac{1}{4}$ , sec. 15, T. 43 S., R. 14 E. This discovery was reported to R. P. Fischer, USGS, Grand Junction, Colorado, in an informal memorandum dated June 19, 1952. This memorandum was transmitted to GJEB, and to the AEC as TEM-353, "Unclaimed mineralized area in the Shinarump conglomerate, northwest of Oljeto Trading Post, Utah," by D. E. Trimble. The deposit is in the Shinarump conglomerate near the base of a channel near the southwest tip of a mesa immediately northwest of Oljeto Trading Post, Utah. The deposit is strongly radioactive and will cause the Geiger counter to register well up on the two scale over a vertical extent of at least 10 feet and a lateral distance of at least 10 feet and a longitudinal distance of at least 20 feet, and in some places on the face will cause the Geiger counter to register as high as 2-3 on the twenty scale. Minor secondary copper minerals are partly concealed by talus near the base of the exposure and some minor secondary yellow carnotite (?) "bloom" is present. The dominant radioactive mineral, however, is thought to be a black crystalline mineral (uraninite ?) disseminated through the sandstone that composes the ore-bearing formation at this point. The mineral is inconspicuous without hand-lens examination. The deposit would not have been discovered without a Geiger counter.

Inasmuch as this discovery lies within the general area in which the Grand Junction Exploration Branch of the Commission is doing some drilling, it is anticipated that they may wish to explore the possibilities of the area further. The Monument Valley, Utah, project hopes to be able to follow any further exploration or investigation of the discovery to gain geologic information that may help guide our work in the Monument Valley area.

Field work on the project will probably be completed on or about September 1, 1952. Upon completion of field work, the party will return to headquarters in Denver where laboratory studies will be made of field samples and a report of investigations will be prepared.

White Canyon project, by A. F. Trites

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

During April, TEM-325, "Preliminary report on the White Canyon area, San Juan County, Utah" by W. E. Benson, A. F. Trites, E. P. Beroni, and J. A. Feeger was revised for publication as a Geological Survey circular. Preparation of TEI-240, "Uranium and copper deposits of the Gonway and North Point claims, White Canyon area, San Juan County, Utah" by A. F. Trites, E. P. Beroni, and W. E. Benson was continued.

Field work on the White Canyon project was resumed on May 1, 1952. Areal mapping was started near Hite in the lower part of White Canyon. Of the approximately 220 square miles scheduled to be mapped during this field season about 50 miles was mapped during the months of May and June. In addition about 7 square miles of Shinarump conglomerate outcrop were examined in detail and several claims were studied and sampled. Of these claims, one, the Jomac claim, will be studied in greater detail for it is located in an area of intense faulting.

The following geologic work is planned for the next quarter: (1) detailed mapping of the Happy Jack mine to determine the relationship of the ore body to fractures, (2) detailed mapping of the Hideout claim, to determine the suitability of the area for physical exploration, and (3) continuation of the areal mapping.

Capitol Reef project, by J. F. Smith, Jr.

The objectives of the Capitol Reef project, Wayne County, Utah, are to map and study the Triassic rocks, particularly the Shinarump conglomerate, to

determine the habits of and guides to uranium ore deposits, and to select favorable areas for physical exploration. In addition the project is planned to map and study the general geology of the area to determine the habits and any regional geologic controls of the uranium deposits.

Preparation was continued of TEI-203, "Progress report on geologic studies in the Capitol Reef area, Wayne County, Utah" by J. F. Smith, Jr., E. N. Hinrichs, and R. G. Luedke. Laboratory study of collected samples was continued. Field work was resumed on May 19.

Plans for the next quarter are to continue the geologic mapping and studies; these will include examination of some exposures of the Shinarump conglomerate south and west of the Capitol Reef National Monument.

#### Stratigraphic studies

##### Morrison formation, by G. A. Williams

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

Compilation of data and preparation of reports and maps were continued in the period of this report. This work is preliminary to the preparation of a final report of the Morrison study. Data compilation of the sedimentary structure study, lithofacies study, and sedimentary petrology study of the Morrison formation have been essentially completed during this quarter. The regional stratigraphic study and pebble study continued compilation of data,



A brief field trip was made during April to augment and complete the data in northwestern New Mexico and northern Arizona for several of the studies.

Noteworthy results of the work during this quarter were the observation that the sedimentary structures of the Recapture and Westwater members of the Morrison formation support the concept that the source area lay to the ~~north~~ ~~south or southwest~~, in southwestern New Mexico or southeastern Arizona. The pebble studies suggest that, although the Westwater and Recapture members were derived from similar terrains, they may not have been exactly superposed sedimentary wedges, for the coarsest material in the Recapture was found near Grants, N. Mex., about 40 miles east of the coarsest material in the Westwater. Sedimentary-structure studies of the basal conglomeratic sandstone of the Brushy Basin member of the Morrison in southwestern Colorado and southeastern Utah show a radial drainage pattern to the north, northeast, and east from south-central Utah. This pattern is similar to the drainage pattern of the underlying Salt Wash member but is not identical. It is not certain that the minor difference of drainage directions between the two members is of regional paleogeographic significance. Detailed tracing of the Morrison outcrops along the Glen Canyon of the Colorado River in south-central Utah indicates that the Morrison does not intertongue and pass southwesterly into the underlying Cow Springs (or Bluff) sandstone, but pinches out as a result of increasing magnitude of pre-Dakota erosion. The Morrison does intertongue, however, with the Cow Springs sandstone in the vicinity of Gallup, N. Mex.

The data compilation and report preparation of all phases of the stratigraphic studies of the Morrison will be recessed until October or November 1952.

Triassic ( pre-Morrison) formations, by G. A. Williams

Stratigraphic studies of the Triassic formations of the Colorado Plateau were planned to obtain needed information regarding distribution, local and regional variations in lithology, source and character of constituting material,

conditions of deposition, and the post-depositional history of the ore-bearing Shinarump conglomerate and associated formations.

The 1952 field season on the Triassic formations was started in the Kanab area, Kane and Washington counties, Utah, during May. Regional stratigraphic study indicated that in this area, the type locality of the Shinarump conglomerate, the formation was essentially as the earlier workers recognized it, a basal conglomerate to the overlying siltstone and claystone sequence of the Chinle formation. Sedimentary-structure studies indicate a southerly source for the Shinarump of the Kanab area. Pebble studies of the Shinarump conglomerate in the same area indicate that the pebble composition is predominantly quartz, quartzite, and chert. The studies indicate that the change in quartz content is small, but from central Kane County westward to eastern Washington County, a marked decrease in quartzite pebbles (60 to 34 percent) is evident. This may represent a real paleogeologic variation but may also be a freak of sampling to be checked by future work.

The sedimentary petrology laboratory essentially completed the analysis and compilation of the data on the Triassic samples collected in the 1951 field season.

The Triassic field studies will be continued during the next quarter. The work will be directed almost entirely to study of the Triassic formations of south-central and southeastern Utah. The field work will begin in the Circle Cliffs, Garfield County, and proceed to Capitol Reef, Wayne County, during the next quarter.

#### Structural history and igneous geology (Cenozoic studies) by C. B. Hunt

The program of study of the Cenozoic structural history and igneous geology of the Colorado Plateau was proposed first in the plans and budget for fiscal-year 1953; however, investigations directed to this program were

carried on during this quarter and even prior to this quarter, not to mention the extensive backlog of geologic information that has been accumulated by the Geological Survey in the past years and which contributes to this program. Because of the activity during this quarter, the program is reported here as an integral part of the Colorado Plateau geologic studies.

The overall objectives of the program of study of the structural history and igneous geology is to learn as much as possible about the Cenozoic history of the Colorado Plateau in order to contribute additional information about:

- 1). The history of the orogenic and epeirogenic movements to which the Plateau has been subjected,
- 2). The history, including the mechanics of intrusion, differentiation, and pneumatolytic processes in and about the igneous bodies on the Plateau, and
- 3). The stratigraphy of the glacial, alluvial, colluvial, and eolian deposits on the Plateau.

#### Glacial stratigraphy, late Tertiary, and early Pleistocene gravels

The orogenic structures that may have contributed to localizing some of the uranium deposits are being mapped as part of the geologic mapping program; the Cenozoic studies are concerned primarily with trying to date the different movements and these studies must be made in areas containing Cenozoic deposits. The epeirogenic uplift of the Plateau has raised it a full mile; the Cenozoic studies are to develop information about the successive movements.

Stratigraphic studies of the glacial, alluvial, colluvial, and eolian deposits, particularly those of Quaternary age, are to develop information about the successive changes in climate and the resulting changes in ground-water level and type of weathering that must have influenced the secondary processes operating on the uranium deposits.

Completion of the study of glacial stratigraphy in La Sal Mountains, Grand and San Juan Counties, Utah, and the discovery there of extensive pre-Wisconsin glacial deposits has again raised the question whether the scarcity

of such deposits in the High Plateau of central Utah might be due to Quaternary structural movements. A start has been made in unravelling the alluvial stratigraphy of the Colorado River; interbedded with one of the fills, 135 feet above the river near Hite, Utah, was found carbonate spring deposits that seem to record a high ground-water table during early Wisconsin time.

Future plans call for a re-examination of the glacial and other Quaternary deposits in the High Plateaus to determine whether the reported scarcity of pre-Wisconsin glaciation in the High Plateaus is apparent or real; and if real, to determine whether it can be attributed to Quaternary uplift. Alluvial, colluvial, and eolian deposits in southeastern Utah and southwestern Colorado will be reconnoitered, partly for stratigraphic information and partly to define areas where detailed examination is desirable.

#### Laccolithic mountains

The laccoliths and stocks on the Colorado Plateau have been the subject of study by the U. S. Geological Survey for many years. In continuing these studies increasing attention is being given to the possible relationships between the intrusive centers and the uranium deposits around them and to the processes by which certain of the intrusions have become enriched in radioactive materials.

The igneous studies have determined that radioactive materials occur in at least moderate abundance in the stock in North La Sal Mountain, Grand County, Utah. There is no evidence as yet to indicate whether or not the deposits are of economic interest but full attention is being given to them in order to learn what is possible about the behavior of radioactive elements in magmatic solutions. A TEM report by Henry Faul and C. B. Hunt concerning the occurrence of radon in the Dillon Tunnel, North La Sal Mountain, is in preparation.

During the next quarter North La Sal stock will be mapped on a scale of 1:14,400 and both the magmatic and pneumatolytic facies of the stock will be

systematically sampled. A report on this work and on the general 1:63,360 mapping that has been completed will be prepared this fall.

Ground-water studies  
by D. A. Phoenix

Ground-water studies are being undertaken in order to test the capacity of the rocks on the Colorado Plateau to transmit ore-bearing solutions to the sites of the known deposits in all ore-bearing formations, and at various times in the geologic history. The accomplishment of this objective may ultimately permit delineation of the "plumbing system" through which the uranium and vanadium minerals may have been introduced to the ore-bearing rocks, as well as permit a partial evaluation of the chemical character of the solution that served as their vehicle of transportation.

Basic data leading to these objectives have been obtained by the ground-water studies of the Morrison formation carried on from 1949 to 1951. These data suggest, 1) that rocks favorable to ore deposits will readily transmit water but that rocks unfavorable to ore deposits will not, 2) that clusters of deposits in at least three widely separated areas are localized beneath a stream-laid conglomerate stratum, 3) that perched ground water moves slowly through the ore-bearing rocks and, 4) that the uranium ion concentration in the ground water is slightly higher near the deposits than away from them.

Transmissability and permeability studies of all the ore-bearing formations in the Colorado Plateau are planned for fiscal-years 1953 and 1954. Time will be devoted during the next quarter to orient new personnel with the past ground-water work and to prepare a preliminary plan for detailed activities. Facilities of the Bureau of Mines, the Ground-Water Branch of the Geological Survey and several private concerns will be investigated as possible sources for permeability determinations.

A ground-water report, TEI-161, "Present and past ground-water conditions in the Morrison formation," by D. A. Phoenix, giving data collected by the earlier ground-water studies is in preparation.

Further activities during the summer months will be devoted to a statistical analysis of the association of the clusters of Morrison ore deposits below overlying lenses of conglomerate. Data bearing upon this association will be collected from diamond-drill logs as well as in the field.

Resource appraisal  
by W. I. Finch

The resource studies are designed to obtain a better evaluation of data on the distribution, reserves, and production of carnotite ores over the region, in order to provide a basis for the Commission's uranium-procurement policy, to aid in preparing long-range plans for mining and milling operations, and to help in selecting areas for future exploration.

Prior to fiscal-year 1952 these studies were made on a part-time basis when personnel were available. During fiscal-year 1952 the program has been a small but continuing program. Plans call for an increase in scope of the work in fiscal-year 1953, partly as a result of transferring some of the functions of the claim-inventory unit to the resource-appraisal unit and partly to increase and speed the appraisal work.

District appraisal studies

The objectives and functions of this project are to compile production and reserve data, to prepare special reserve studies, and to supervise and guide part-time resource studies by exploration geologists. The project is also processing drill core and other assays and distributing results to the proper persons.

During this quarter no Preliminary Reserve Statements were prepared.

TEM-300, "Preliminary appraisal of the carnotite resources of the Carrizo Mountains area, San Juan County, N. Mex., and Apache County, Ariz., was transmitted to the AEC in June.

Future plans call for the preparation of Preliminary Reserve Statements as warranted by the results of exploration. During the next quarter H. G. Stager will undertake the necessary field work to appraise resources of the eastern part of the Gateway district, Mesa and Montrose Counties, Colo.

#### Pre-Morrison resource appraisal

The objectives of the pre-Morrison resource appraisal are to obtain a general evaluation of uranium deposits in pre-Morrison formations, particularly the Shinarump conglomerate; to determine and recommend areas favorable for exploration, or areas in which geologic mapping or other specialized geologic studies are desirable; to determine the habits of uranium occurrence in the pre-Morrison rocks and the distribution or zoning of various features such as elements and types of deposits and compare these with the known features of the Morrison uranium deposits in hope of establishing precisely the factors common to uranium deposits of the Colorado Plateau region.

During the past year uranium deposits in pre-Morrison rocks have been examined in 17 areas in the Colorado Plateau. In addition considerable time was spent in detailed mapping of the Shinarump #1 mine, Seven Mile area, Grand County, Utah. Selected geologic samples were taken for thin and polished section, stripping film, spectrographic analysis, and mechanical analysis.

In the area between the Colorado and Green Rivers, a relationship exists between the localization of the uranium deposits and the lithology of the Shinarump conglomerate. If one examines McKnight's (Geology of area between Green and Colorado Rivers, Grand and San Juan Counties, Utah, USGS Bulletin 908, 1940) map of the inter-river area, one will note that the typical Shinarump conglomerate pinches out along an east-west line. Only a few isolated

outcrops of Shinarump were mapped north of this line, although many outcrops of typical Shinarump were not mapped by McKnight because of the scale of his map. To date all but one of the uranium deposits reported in the Shinarump conglomerate lies north of this line. Field inspection of uranium deposits in this area indicates that the individual deposits are located at the margins of lenses or where the conglomeratic sandstones pass in large part into siltstones and other finer sediments. This relation is not pronounced in the Seven Mile area, 12 miles north of Moab, Utah. The relation should prove useful as a guide to ore in physical exploration (bulldozing of outcrop or drilling) in the inter-river area. Because of the location of deposits in less competent beds, many favorable outcrops are covered by talus. Botanical prospecting along these talus slopes might serve to evaluate the covered areas prior to any proposed exploration program. It may be mentioned that selenium-indicator plants were noted below the outcrop of the deposits in the Bow Knot, Taylor Canyon, and Seven Mile area, Emery and Grand Counties, Utah.

Plans call for the continuation of these investigations by examination of 10 specific areas and by detailed mine mapping. Tentatively a detailed mine map will be made in each of four of the areas. A preliminary report summarizing the results of the investigations will be prepared at the end of this field season.

Mineralogic studies  
by L. B. Riley

General mineralogic studies

Four reports by A. D. Weeks related to the mineralogy of the Colorado Plateau have been in preparation during this quarter. Their titles and abstracts indicate the character and results of the general mineralogic program.



1. "Summary report on mineralogic studies of the Colorado Plateau through April 30, 1952," by A. D. Weeks, TEM-431, to be transmitted in July 1952.

"Uranium minerals identified from the Colorado Plateau include uraninite and pitchblende, hydrous oxides, carbonates, sulfates, phosphates, arsenates, vanadates and silicates. Several other minerals as well as organic material containing small amounts of uranium have been studied. Vanadium and copper, the chief metals associated with the uranium, occur in many minerals. The minor metals include lead, zinc, cobalt, nickel, manganese, silver, molybdenum, gold, arsenic, and selenium. Recent work suggests that carnotite ore is restricted to near-surface deposits in the zone of oxidation and that deeper ores are black with a quite different mineralogy from the carnotite ore."

2. "Summary report on Colorado Plateau clay studies through April 30, 1952," by A. D. Weeks, TEM-437, to be transmitted in July 1952.

"The several aspects of Colorado Plateau clay studies included adaptation of qualitative and semiquantitative methods of identifying clay minerals, study of chief clay minerals and water-soluble minerals in 50 mudstone or siltstone samples of Jurassic and Cretaceous formations from western Colorado and eastern Utah, study of red and gray clays underlying ore-bearing sandstone in Colorado and Arizona, and study of "vanadium clay."

These studies have shown 1) that the "altered gray clay" beneath the uranium deposits of the Morrison formation contains less ferric iron and less total iron than the common red clays of the Morrison formation, 2) that clay minerals have a distinct stratigraphic segregation in the Morrison formation that is significant in the interpretation of depositional environment and may be significant to the origin of the uranium deposits, and 3) that the vanadium-bearing clays of the Morrison uranium ores probably contain more than one vanadium clay mineral.

3. "Mineralogic study of some Jurassic and Cretaceous claystones and siltstones from western Colorado and eastern Utah," by A. D. Weeks.

"The clay minerals and water-soluble minerals were identified in 50 samples

of siltstone and claystone representing formations from the Summerville of Jurassic age to the Dakota of Cretaceous age, from four localities in western Colorado and four localities in eastern Utah. Semiquantitative spectrographic analyses and radiometric counts are given for all the samples. Results of size analyses made by R. A. Cadigan are included."

These studies show that montmorillonite is the chief clay mineral in the Brushy Basin member of the Morrison and hydromica is the chief clay mineral in the Salt Wash member of the Morrison. The montmorillonite is of volcanic origin and represents an altered volcanic tuff or ash. Whether uranium has been or is being leached from the montmorillonitic clays has not been determined, but the samples studied do not show above-average radioactivity, and no water-soluble uranium minerals are indicated.

4. "A second occurrence of bayleyite in the United States." (A short paper for the American Mineralogist by T. W. Stern and A. D. Weeks).

"Bayleyite is a magnesium uranium carbonate first described from Arizona in January 1951 by Axelrod, Grimaldi, Milton, and Murata of the U. S. Geological Survey. The second U. S. locality is at Hideout mine, White Canyon district, Utah."

A. D. Weeks attended the AEC uranium mineralogy conference of April 18, 1952 (New York) and reported on recent developments in the mineralogic studies on the Colorado Plateau with particular attention to uraninite, rauvite, and other uranium minerals. On May 5, 1952, L. B. Riley presented an informal oral report in Grand Junction on the mineralogy of the Colorado Plateau ores, especially as related to ore findings; differences between oxidized and pre-oxidized ores; and between presence and absence of vanadium in excess of that required for carnotite.

In connection with studies of the black uranium ores of the Colorado Plateau, a sample from the Arrowhead mine, Gateway district, Mesa County, Colo.,

has yielded a new uranium mineral, giving an X-ray powder pattern similar to that of zircon and thorite. This pattern has also been obtained from ore samples from two other mines in the Gateway district and one mine in the Paradox district, Colorado-Utah. Samples of black ore from the Whitney mine and the Bitter Creek mine, both in the Uravan district, Montrose County, Colo., proved to be mon-troseite ore containing a few percent of a uranium mineral probably like the new mineral from the Arrowhead mine. Extensive analytical work on these black ores and their mineralogy is continuing.

An X-ray pattern of uraninite was obtained from a sample from the Camp Bird No. 13 mine, Temple Mtn., Emery County, Utah. Some black and yellow ore from the Pumpkin Butte area, Campbell County, Wyo., studied in part as a comparison to the Colorado Plateau ores, was found to consist chiefly of uranophane and manganese and iron oxides.

#### Distribution of minor elements

The program for investigation of the distribution of minor elements on the Colorado Plateau, has as its objective the examination of the relationship between uranium deposits and other types of ore deposits and igneous rocks on the Colorado Plateau in an effort to determine the origin of the bedded uranium ores, and to develop the criteria for the recognition of areas containing large ore deposits.

Preliminary studies have yielded encouraging results which are summarized in a Trace Elements report to be transmitted to the AEC entitled, "Distribution of ore deposits and spectrographic analyses of some rocks and ores on the Colorado Plateau," by E. M. Shoemaker and L. B. Riley.

"The geographic pattern of known igneous rocks and ore deposits on the Colorado Plateau suggests a zonal arrangement of several types of ore deposits around centers of igneous activity.

"Spectrographic analyses of rocks and ores on the Plateau have been

obtained in an effort to determine the distribution of elements and to examine the relationships between types of ore deposits and between the ore deposits and igneous rocks. Over 170 analyses of rocks and ores are given in this report. A preliminary study of these analyses suggests that the proportion of uranium, vanadium, copper, and silver in the uranium ores varies geographically, and that the pattern of variation may be in part concentric about some of the major laccolithic intrusions. It is also suggested that the following ratios of metals contained in the uranium ores are possible guides to larger-than average ore deposits: (1) lead/uranium greater than 1, (2) lead/zinc greater than 10, (3) zinc/geometric mean of cobalt and nickel less than 10."

Several specific lines of research are planned for the investigation of distribution of elements in fiscal-year 1953. A large file of pulp samples representing several hundred mines on the Colorado Plateau will be collected. Many individual deposits will be studied in the field and sampled extensively. A large suite of samples of sedimentary rocks, especially of the principal ore-bearing formations, will be collected; many samples collected for stratigraphic studies will be used. Finally, a reconnaissance study and sampling will be made of all the igneous rocks of the Colorado Plateau. All the samples collected will be analyzed by spectrographic or chemical methods. The results of the chemical analyses will be studied to determine the mode of occurrence and pattern of distribution of the elements in the sedimentary formations, in the igneous rocks, and the bedded uranium deposits. It is hoped that the comparison of these results will throw light on the origin of the bedded uranium ores and specifically will point to areas favorable for physical exploration for new ore deposits. The work will probably progress slowly during the coming quarter but will accelerate in September with the return of E. M. Shoemaker from other duties and the assignment of an additional man to the project.

Geophysical prospecting  
by W. E. Davis

Geophysical investigations of carnotite deposits are being made to evaluate the use of various geophysical prospecting methods as possible guides in the search for carnotite ores on the Colorado Plateau. Electrical and magnetic methods have been tested over shallow deposits in the Salt Wash member of the Morrison formation. The electrical methods have proved to be the most applicable and have been continued during this quarter in unexplored areas to obtain information that may be helpful in future drilling.

Resistivity and natural-potential surveys were made in the western part of the Yellow Cat district, Utah. The resistivity-depth curves do not show discontinuities that would serve to determine thickness of the individual sandstone strata. However, the measurements at a depth of 200 feet show two anomalous areas that are interpreted as overlying thick sections of mudstone. The sandstone strata in these areas are probably too thin to be favorable for ore. A statement recommending only limited drilling in these areas is being prepared for future reference in connection with exploration plans in the Yellow Cat district. The natural-potential measurements show several anomalies that seem to be caused by small topographic features and changes in surface material rather than changes in subsurface conditions.

Resistivity and natural-potential surveys were run in the vicinity of the Gramlich mine in La Sal Creek area, Colo. As this work has just been completed, interpretation of the data has not progressed sufficiently to evaluate the results.

Gravity measurements were made with Frost and Worden instruments along two traverses crossing favorable sandstone conditions in the Spud Patch area, Colo. These measurements show no anomaly over the thicker and more favorable parts of the ore-bearing sandstone.

Resistivity measurements made previously on Atkinson Mesa, Colo. to depths ranging from 500 to 700 feet failed to show any expression of the occurrence of thick sandstone in the Salt Wash member. Additional measurements were made using a 7 1/2 KW power unit to supply higher current and thereby magnify small anomalies at depth. Increasing the current density at which the measurements were made simply had the effect of smoothing out small irregularities in the resistivity-depth curves. There was no expression of the change from thick sandstone to thick mudstone sections. There are large changes in the resistivity of near-surface beds between different parts of the area but these changes do not correlate with the underlying rock strata.

During the next quarter geophysical investigations will be made of channel structures in the Shinarump conglomerate in Monument Valley, Ariz. Resistivity (horizontal and depth profiling measurements), natural potential, and gravity surveys will be made to determine the size and shape of these structures.

## VEINS, IGNEOUS ROCKS, AND RELATED DEPOSITS

Colorado Front Range mineralogic, geochemicaland petrologic studies

by George Phair and Kiyoko Shimamoto

The quarter was spent in finishing the preparation and editing of the two following reports:

"Radioactive Tertiary porphyries in the Central City district, Colorado, and their bearing on pitchblende deposition," by George Phair. This report is now in process and will be issued as TEI-247.

"Notes on the differential leaching of uranium, radium, and lead from pitchblende in  $H_2SO_4$  solutions," by George Phair and Harry Levine. This report is now in process as a TEI and an abstract of it will be given at the G. S. A. in November.

A summary of the main conclusions presented in the paper on "Radioactive Tertiary Porphyries" follows:

The pitchblende deposits of the Central City district were formed shortly after the intrusion of a quartz-rich, lime-poor variety of bostonite not previously recognized in the region. Sixteen out of seventeen known occurrences of pitchblende, including all commercial deposits, are localized within 500 feet of a quartz bostonite dike.

These quartz bostonites are among the most radioactive igneous rocks in the world, containing up to 25 times as much equivalent uranium as the best available average for granitic rocks. Individual samples contain as much as 0.01 percent uranium and 0.05 percent thorium.

The high thorium and uranium contents are primary features of the dikes. Like other abnormally radioactive intrusives, including the less radioactive biotite granite of Conway, N. H., and the more radioactive Nigerian riebeckite granite recently described, the quartz bostonite represents the silica-rich member of an alkaline intrusive sequence, all members of which show some enrichment in equivalent uranium and uranium over the published averages for granitic rocks.

Our interpretation, based upon both field and laboratory studies, is that the hydrothermal solutions responsible for the regional pyritic-gold mineralization became locally enriched in uranium in the vicinity of bodies of uraniferous quartz bostonite cooling at no great depth, and that these same solutions

became further enriched in uranium by the leaching of quartz bostonite channelways enroute to higher levels. Here, as throughout the Front Range, the porphyry dikes served as flues to conduct volatiles and aqueous solutions to higher levels.

A nearly complete replacement of the sparse, early formed mafic silicates in the bostonites by "high-temperature" magnetite and specularite indicates a late-magmatic period of oxidation just prior to the onset of hydrothermal conditions. The simultaneous oxidation of  $U^{4+}$  to  $U^{6+}$  to be expected on chemical grounds probably made the uranium susceptible to leaching and transport by the hydrothermal solutions. Not until reducing conditions returned with falling temperature was the uranium deposited as pitchblende along with the sulfides (pyrite and chalcopyrite) in the nearby veins.

Toward the end of the quarter Phair left for summer field work in the Colorado Front Range.

The search for centers of intrusion of quartz bostonite and of other radioactive porphyries, will be coordinated so far as is possible with the ore-zoning studies of B. F. Leonard and others. Leonard's studies, based largely upon the available literature, strongly suggests that the pitchblende is concentrated in the Front Range in the zone characterized by high copper content, transitional between the pyritic-gold zone and the zinc-lead silver zone. The two lines of study, the one on the igneous sources, the other on the ore habit, mutually supplement each other. Our hope is that the study of the igneous sources will be useful in blocking out areas for systematic uranium reconnaissance, and that the studies of the ore zoning will show where, within such areas, the probabilities are highest for finding workable deposits.



GEOCHEMISTRY AND PETROLOGY OF LIGNITES  
by J. M. Schopf and Maurice Deul

Geochemical, mineralogic, and petrologic investigations of lignites proceeded slowly during most of the quarter with an increase in activity towards the end of the quarter.

In May at several conferences attended by interested personnel from both the Fuels Branch and the Geochemistry and Petrology Branch of the Survey the details of the laboratory investigations of uraniferous lignites were discussed. General agreement was reached on the approach to the specific problem of the distribution of uranium in lignites and on the more general problems of mineralogic composition and the geochemistry of lignite. An outline of the laboratory investigations as planned is given below. A conference with Prof. T. F. Bates of Pennsylvania State College showed that there is no conflict between the Survey's program and that of any other AEC contractor whom we know to be working on uraniferous lignite.

The outline as presented makes no reference to the extensive and detailed field investigations conducted by the Fuels Branch field parties and also the incidental field investigations of other Survey parties and AEC contractors. Most of the efforts expended in the detailed laboratory investigations are on samples collected by Fuels Branch field geologists and on cored samples drilled under their direction. The progress of field and laboratory work is reported quarterly and the results of these studies are irregularly issued as Trace Elements Investigations or Trace Elements Memorandum Reports.

The laboratory investigations on uraniferous lignite are conducted at the Fuels Branch Coal Geology Laboratory at Columbus, Ohio (CG Lab.) and at the Geochemistry and Petrology Branch Trace Elements Section Washington Laboratory (TE Lab.).

Outline of laboratory investigations

- A. Standard coal sample treatment (CG Lab.).
  - 1. Preparation of detailed core description (megapetrography).
  - 2. Preparation of Bureau of Mines analytic samples (see C below).
  - 3. Preparation of TE analytic samples (see B below).
  - 4. Core reserve preparation for detailed investigation (see D etc. below).
- B. Standard TE analytic suite (TE Lab.).
  - 1. Radiometric determinations (reported as eU).
  - 2. Ash preparation (use in B-3 and B-4).
  - 3. Chemical uranium determinations.
  - 4. Semiquantitative spectrographic analysis of coal ash.
- C. Standard Bureau of Mines analytic suite (Coal Analysis Section, Pittsburgh).
  - 1. Proximate and ultimate analyses; determinations of calorific value of coals, total sulfur and forms of sulfur, and fusibility of coal ash.
  - 2. Analytic requests prepared by CG Lab. Columbus; analytic reports returned to and distributed from CG Lab.
- D. Coal micropetrographic study (CG Lab.)
  - 1. Determination of anthraxylon, translucent attritus, opaque attritus, and petrographic fusain (based on reserve blocks stored in water pending preparatory work).
  - 2. Strip-film study of selected thin sections (interpretation cooperatively by CG Lab. and TE Lab.).
- E. Special sample preparation and U determination (CG Lab. and TE Lab.).
  - 1. Determinations of U concentration in sediments associated with coal

(radiometry at CG Lab in part and radiometry and chem. U determination in part at TE Lab.).

2. Selection and determinations from samples in high U concentration zones. (Sample selection and monitoring of microsamples at CG Lab.; radiometry in part at CG Lab; radiometry and U determinations at TE Lab.).

F. Solid-phase mineral segregation studies (TE Lab.).

1. Standard mineral separation by heavy liquids, magnetic, and electrostatic methods; quantitative mineralogy with radiometric and chemical U determinations on the various fractions.
2. Basak fine grinding oil separation.
  - a. Petrographic determinations from mineral concentrate.
  - b. Electron-microscope studies of appropriate sized fractions.
  - c. Stage determinations of carbon, carbonate, and ash to determine specific mineral-free correction for organic portion of impure carbonaceous rocks.

G. Solid-phase organic segregation studies (CG and TE Labs.).

1. Separation of resinous bodies from lignite by coal-maceration techniques (CG and TE Labs.).
2. Identification of specific resinous bodies by X-ray diffraction and physical-chemical methods and paleobotanical identification (CG and TE Labs.)
3. Mechanical separation of resinous bodies from thin sections and polished sections by use of appropriate tools held by a micro-positioner; identification and determination of uranium content of specific resinous bodies. (CG and TE Labs.).
4. Determination of coal components by appropriate differential thermal analysis techniques (TE Lab.).

#### H. Liquid-phase segregation studies (CG and TE Labs.).

Use of modified Fischer retort on high U concentration zone samples; radiometry of residue and products; spectrography of suitable products; possibility of further chem. investigations.

1. Laboratory distillation (TE Lab.).
2. Oxidation-dispersion (joint study CG and TE Labs.) study of fractions soluble and insoluble derived from chem. oxidation and fractional separation of regenerated humic acids and microscopic selection of residual components.
3. Laboratory batch hydrogenation studies; study of converted hydrocarbons, flushed heavy oil, and mineral complement of residue (TE Lab.).
4. Hydrocarbon solution at moderate temperatures using anthracene and similar compounds (CG Lab.).

#### I. Studies of composition of pure liquid-phase and solid-phase organic extracts (TE Lab.).

1. Setting up appropriate analytical scheme to determine C, H, O, N, and S on microsamples.
2. Investigation using infrared adsorption spectroscopy as a means of identifying compounds.
3. Studies of correlation of uranium to tannis and humic substances.

Equipment in the form of an additional biological microscope, and a petrographic microscope was obtained for the Fuels Branch Coal Geology Laboratory. Further modification of existing radiometric equipment was made to permit monitoring of microsamples for special sampling.

The highest priority in the current investigations is given to the separation and identification of all minerals present in sink-float concentrates from lignite. It is indicated that the best preliminary mineral

separations are obtained from the fine fractions, at least -200 mesh, with the aid of a centrifuge.

In the Trace Elements Section laboratory no further progress was made with the tannin extraction studies because of the shortage of personnel. The work will be carried on in the next quarter under I. A. Breger's direction. Other work, as outlined in sections G, H, and I, will follow in logical sequence as equipment arrives and is placed in operating order.

## PHOSPHATES

40

Northwest phosphate  
by R. W. Swanson except as noted

### Areal geologic mapping

#### Dry Valley quadrangle, Idaho, by E. R. Cressman

The map, structure sections, and a text have been prepared for the Dry Valley quadrangle (NE $\frac{1}{4}$  of the 15-minute Slug Creek quadrangle) and will be transmitted as a TEI report and also placed on open file in the near future. The areal geology was transferred to the published topographic map (1:24,000) and an autopositive made from which ozalid prints have been produced. The structure sections have been reproduced in a similar manner, and the text has been mimeographed.

Pre-Tertiary sedimentary rocks ranging in age from Mississippian to Triassic are exposed in the Dry Valley quadrangle. The Brazer and Wells formations of Carboniferous age, the Phosphoria formation of Permian age, and the Dinwoody and Thaynes formations of Triassic age crop out in the mountains, and the valleys are underlain by Tertiary and Quaternary sediments. The Phosphoria formation is approximately 500 feet thick, the lower 180 to 200 feet comprising the phosphatic shale member. The Phosphoria formation is overlain by approximately 3,200 feet of Triassic beds and underlain by 2,800 feet of Carboniferous rocks.

The most prominent structural feature is Schmid syncline which tends north-northwest across the center of the quadrangle. Dips on the flanks are moderate, and both ends plunge slightly toward the center. The Thaynes formation is exposed along the axis. The west limb is complicated by both normal and reverse longitudinal faults. The Phosphoria formation swings around the south nose of the syncline dipping from 15° to 20° to the northeast and north. The phosphatic shale also crops out on the north part of the west limb, but it

is thinned and in places cut out by faulting. On the east limb, the Phosphoria crops out through the fill of Dry Valley on several isolated hills.

Immediately west of Schmid syncline, the structure is obscured by Cenozoic deposits, but in the extreme southwest corner of the quadrangle, as in the adjacent Johnson Creek quadrangle, the structure is known to be complex and much faulted. In this area the Phosphoria formation is exposed in several small fault blocks and in the overturned west limb of a syncline.

The Dry Valley anticline borders the Schmid syncline on the east. The lower Wells formation on the top of the Brazer formation crops out along the axis. A normal fault is nearly coincident with the anticlinal axis, and there are several minor folds on the west flank. The Phosphoria formation on the east flank of the anticline is exposed on Dry Ridge where it dips from  $25^{\circ}$  to  $35^{\circ}$  to the east. The southernmost part of this outcrop belt of Phosphoria is thinned and in places cut out by a longitudinal high-angle fault.

In the extreme northeast corner of the quadrangle the moderately dipping east limb of the Dry Valley anticline is thrust northeastward onto a tightly folded slightly overturned syncline of Thaynes and Dinwoody rocks.

#### Johnson Creek quadrangle, Idaho, by R. A. Gulbrandsen

The compilation and drafting of geology of the Johnson Creek quadrangle (NW $\frac{1}{4}$  of the Slug Creek 15-minute quadrangle) in Caribou County, southeastern Idaho, has been completed, and the map is being reproduced by Ozalid process for transmittal as a TEI report and for open-file release. It will be released as two sheets: one with geology and explanation and the other with structure sections superimposed.

The geology of the quadrangle is very complex with folding and faulting evident on a grand scale. Folds have been faulted, partially cut out, and

repeated to such a degree that their nature is largely obscured in many places. The main structural element of the quadrangle is a syncline (the Trail syncline of Mansfield) whose axis trends a little west of north and which forms the central part of the quadrangle. It is bounded by major faults on the west and east sides. Fault blocks of smaller dimension but of greater structural complexity are found on the eastern and western margins of the quadrangle. Triassic rocks make up most of the central and northern portions of the quadrangle with mostly upper Paleozoic rock composing the other portions.

The Phosphoria formation has been mapped as two units: the Phosphatic Shale member (Pps) and the overlying Rex member (Ppr). The Phosphatic Shale member has been measured in two trenches on the east and west sides of the quadrangle. In the west trench (Trail Canyon, lot no. 1206) the thickness of the member is 210 feet, while in the east trench (Johnson Creek, lot no. 1209) the thickness is 145 feet. On the very south-central border of the quadrangle the member is very thin if present at all. For the most part the mapping has indicated that the thickness of the member can be expected to be between 100 and 200 feet. Variations in thickness are to be expected in a structural setting such as found in this quadrangle, due chiefly to near-bedding-plane shearing.

There are approximately 25 miles of linear outcrop of the Phosphatic Shale member within the quadrangle. The longest line of outcrop is that occurring along the western limb of the Trail syncline. It is the best defined line of outcrop and is less complicated structurally than the other lines of outcrop found in the smaller fault blocks of the quadrangle. The range of attitude of the beds is large, from horizontal to steeply overturned, though the long Trail syncline belt of phosphatic shale is fairly uniform in attitude, ranging generally from 30° to 60° east.



Soda Springs quadrangle, Idaho

The Soda Springs 15-minute quadrangle, Bannock, Bear Lake, and Caribou counties, Idaho, is being mapped by F. C. Armstrong. About two thirds of the mapping was completed by the end of the 1950 season, at which time it was recessed, and a preliminary report, including geologic map, structure sections, and detailed columnar sections, was nearly ready for transmittal last summer but has been delayed in its completion by other pressing work related to the Korean situation. This report is now being completed and should be ready for transmittal within a few months.

The Soda Springs quadrangle is critical to the phosphate program for, though it contains a relatively small amount of Phosphoria formation outcrop, it does include the biggest phosphate-producing mine of southeastern Idaho. Furthermore, it contains complex structural elements that are critical to the area of large phosphate reserves in the adjacent area to the east where detailed (1:12,000) mapping of the geology, particularly the phosphate deposits, is in progress.

Rocks exposed in the quadrangle include formations from Lower Cambrian to Lower Triassic in age having a total thickness of about 25,000 feet and Tertiary to Recent continental deposits and lavas. All but the Recent rocks have been folded, and faulting has occurred in rocks of all ages.

The principal contributions of this work are an excellent suite of columnar sections of the marine Paleozoic and Mesozoic formations that record much detailed information formerly unrecorded, and a good re-evaluation of some aspects of the Bannock overthrust. The former should be particularly useful to all further geologic work done in this region, and the latter is of major importance in interpretations of the geologic structure in the Aspen Range-Dry Ridge area of detailed mapping where interpretations involving very large reserves of phosphate are at stake.

Centennial Range phosphate deposits, Montana-Idaho

An area of 15 to 20 square miles, near the crest of the Centennial Range along the Idaho-Montana state line west of Yellowstone Park, that contains potentially minable beds of acid-grade phosphate has been mapped at a scale of 1:12,000 by F. S. Honkala. This area lies mainly in the SE $\frac{1}{4}$  Lyon quadrangle but overlaps into the SW $\frac{1}{4}$  Lyon.

Structurally the Centennial Range represents a tilted fault block with a steep three-thousand-foot scarp face on the north side. In the area of chief concern the Phosphoria formation outcrops near the crest of the range and is overlain by the Triassic Dinwoody formation. Only these two formations were mapped in detail. They dip southward at 12° to 20° beneath younger Mesozoic formations and Tertiary lavas at the edge of the Snake River Plains lava field.

Five members of the Phosphoria formation were mapped and locally two of these were divided into two units each. The B and D members are composed of phosphate rock and black phosphatic shales, and the B member contains, in fact is chiefly composed of, a rich phosphate bed averaging nearly 6 feet in thickness and 31 percent or more P<sub>2</sub>O<sub>5</sub>. The phosphate in the D member is not rich enough to warrant further consideration for mining at this time, and the other members are non-phosphatic, being composed chiefly of chert, limestone, and sandstone.

A preliminary geologic map, a structure-contour map for the top of the B member, an isopach map of the overburden on the B member, and a brief descriptive text have been submitted and are being reviewed prior to submission for open file and probably TEI report. Reserves of B-member phosphate in this area have been computed as in excess of 90 million tons, but this figure will probably have to be revised in accordance with some of the detailed information gathered during the sampling program.

The area is high and remote from rail or any significant population center. On the other hand the simplicity of the structure and the large reserves of phosphate rock above entry level make the area attractive for consideration of a large-scale mining enterprise. In order to start such an enterprise a complete mining camp would have to be built and a 20-25-mile rail spur would have to be built. The B-member phosphate bed could be reached at about the 7,000-foot level by means of a 10,000-foot crosscut northward from the toe of the range.

#### Lyon quadrangle, Montana-Idaho

The Lyon 30-minute quadrangle is being mapped by G. C. Kennedy at a field scale of 1:24,000. This area lies west of Yellowstone Park and is mostly in Montana, but the southern edge is in Idaho. To date more than 2½ 15-minute quadrangles have been mapped, the SE¼, NW¼, N½ of SW¼, and selvages into the remaining areas.

The rocks being mapped range in age from pre-Cambrian to Recent and include most of the major rock types. The pre-Cambrian rocks are metamorphosed sediments; the Paleozoic and Mesozoic formations are typical for, and involve characteristic problems of, southwestern Montana; the Tertiary to Recent rocks are continental deposits including conspicuous lavas. The structures include gentle folding and rather widespread faulting, mostly small-scale but some of major importance.

The earliest mapping was concentrated in that part of the quadrangle, near the south center, containing the best phosphate deposits. On the basis of this early mapping and the phosphate sampling in the area the detailed mapping of the Centennial Range phosphate deposits was started.

In addition to the attention called by this work to the phosphate deposits and to the mapping of the structure and distribution of the rocks in this area, much valuable information has been gathered on the stratigraphy, including the pre-Cambrian metamorphics and the Tertiary and

younger continental deposits, information that will be of great help in unravelling the complicated geologic history of southwestern Montana. It is expected that most of the field work on this problem will be completed this summer. Maps and a brief report on the work completed to date are in preparation and should be released on open file within the next few months.

#### NW $\frac{1}{4}$ Willis quadrangle, Montana

The NW $\frac{1}{4}$  Willis 30-minute quadrangle and the adjacent strategic Brown's Lake tungsten area have been mapped by W. B. Myers. The geologic map has been compiled on a planimetric base at a scale of 1:24,000 and a report is in preparation for open-file release, and a TEI report. The same map and report, with only minor modifications anticipated in the latter, will be published soon in the Mineral Deposits Field Studies series.

The geologic history of this area is unusually diversified and the geology is complex in most of its aspects. The northwest quarter includes part of a large mass of quartz monzonite, to which the tungsten deposits and probably many of the lead, silver, and gold deposits are closely related. In the southwestern quarter are a thick sequence of pre-Cambrian Belt sediments together with Paleozoic formations. Paleozoic and Mesozoic strata overlapped by continental Tertiary and younger deposits, in large part volcanic, occur chiefly in the east half of the area.

The structure in this area is very complex, characterized chiefly by tight folding and thrust faulting, but normal faulting is common, some of it traceable back to the pre-Cambrian at which time the very thick sequence of Belt strata appears to have accumulated just west of a very abrupt shoreline, presumably of fault origin. Some of this faulting persisted into the Cambrian and associated doming into the Devonian.

The mineral deposits include, as well as those mentioned above, copper, iron, and phosphate. Production of these has been small, though that of the lead, gold, and silver has been significant and that of the tungsten deposits,

currently being developed, promises to be large. The phosphate is not rich or thick enough to support mining ventures, and it is too much faulted and folded to encourage mining activities. Some interest has been generated by petroleum possibilities, but the structure is too complicated to offer much encouragement.

Probably the greatest contribution being made by this work, besides production of an unusually fine geologic map, has been the assembly of information necessary to an understanding of the geologic history of the region, for the area occurs at a critical location from the standpoint of both stratigraphy and structure.

#### SW $\frac{1}{4}$ Willis quadrangle, Montana

The SW $\frac{1}{4}$  of the Willis 30-minute quadrangle has been mapped by W. R. Lowell and in addition he has mapped the SW $\frac{1}{4}$  of the SE $\frac{1}{4}$  and an area of similar size near the center of the Dell quadrangle. Maps and a report covering the latter two areas and part of the larger area were released on open file in 1950. The geologic map of the completed 15-minute quadrangle has been compiled at 1:24,000 and it is hoped it can be released soon, either with or without an accompanying text. It will also be published in the Mineral Deposits Field Studies series.

This area is somewhat similar to the NW $\frac{1}{4}$  Willis in its general character and complexity, though many major differences exist. Intrusive rocks make up a small part of the quadrangle, likewise in the northwest quarter of the area, and the pre-Cambrian rocks are, with the exception of one small thrust fault, crystalline metamorphics, none of which are exposed to the north. Volcanic rocks compose a much greater part of this area, chiefly in the eastern part, and early Tertiary sediments of the Beaverhead formation are important, chiefly in the southeastern corner and along the west side.

The mineral deposits exploited to date are chiefly gold and silver.

The phosphate deposits examined are marginal in character and not likely to support a mining enterprise for some years. Other minerals of economic importance include oil shale associated with phosphate in the Phosphoria formation and quartzite being mined for use as a silica flux for the base-metal smelter at Anaconda.

#### Virginia City and Eldridge quadrangles, Montana

An area equivalent to about  $1\frac{1}{2}$  15-minute quadrangles in the Madison and Gallatin Ranges of Montana has been mapped by R. W. Swanson, mostly independent of the Government, and the phosphate deposits of the area were investigated. An open-file report on this area was released early in 1951 but further work on the study has been recessed in favor of more pressing duties. It is hoped that the work may be resumed within the coming year.

The area includes rocks of pre-Cambrian to Recent age and is most valuable for the critical information it sheds on the structural history of southwestern Montana. The phosphate deposits in part of the area are of high grade but are too thin and the area is structurally too complex, topographically too rugged, and geographically too remote from rail transportation to warrant further interest at this time.

#### Stratigraphic studies

##### Correlation studies, by R. P. Sheldon

Correlation studies of the strata of the Phosphoria formation in northwest Wyoming, exclusive of the southern Wyoming and Salt River Ranges, have been in progress early in this quarter. An hypothesis of correlation was previously advanced as shown below:

Table 1.--Correlation of Phosphoria formation members

<u>Bear River, Idaho</u>	<u>Irwin, Idaho</u>	<u>Jackson, Wyo.</u>
Upper shale	Upper shale	E member
Rex chert	Rex member	D member
Phosphatic shale	Phosphatic shale	C member
Upper Wells	Upper Wells	B member
		A member

Further studies from the Jackson Hole area along the east flank of the Wyoming Range to Kemmerer, Wyo., and from there to the Bear River field indicate that the above correlation may not be entirely satisfactory. The E member at the Jackson Hole area can be traced south to Kemmerer along this outcrop. To the west of Kemmerer this member apparently grades into mudstone. Thus the D and E members may be the equivalent of the upper shale in the Bear River field.

A further possible change of former correlation hypotheses is that the upper contact of the Rex member is not consistent as formerly placed and that possibly the upper cherty mudstones of the Rex of southeast Idaho are partial correlatives of the upper shale of Wyoming.

In general, progress of correlation has been good but new problems are arising. More field work and compilation is necessary before a choice between the details of several alternative correlation hypotheses can be made.

#### Sampling program, by R. P. Sheldon

During the last quarter of fiscal-year 1952 a major part of the sampling program was completed. Rainy weather, making work impossible and roads impassable, caused enough delay so that some of the work will be carried over into July. To date three successful trenches, one hand trench and two bulldozer trenches, have been dug, measured, and sampled, and another had to be abandoned due to bad ground and structural complexities. In addition, the phosphatic shale beds at the open pit of the Kemmerer phosphate mine on South Mountain have been measured and sampled, and samples of the lower phosphate beds at the mine were collected. A third successful bulldozer trench on Deadline Ridge was completed, and measurement and sampling of the formation is in progress. A summary of the progress to date at various sample localities is as follows, all in Wyoming:

Table 2.--List of sample localities

<u>Lot</u>	<u>Name</u>	<u>County</u>	<u>Sec.</u>	<u>T.</u>	<u>R.</u>	<u>Samples</u>	<u>Remarks</u>
1377	Middle Piney	Sublette	8	30 N.	115 W.	36	Hand trench
1378	Wheat Creek	Lincoln	4	23 N.	116 W.	46	Dozer trench
1379	Fontenelle	Lincoln	35	27 N.	116 W.	50	Dozer trench
--	LaBarge	Lincoln	9	28 N.	116 W.	--	Unsuccessful trench
1380	South Mtn. mine	Lincoln	9	23 N.	116 W.		Open pit
	Deadline Ridge	Sublette	8	27 N.	114 W.		Dozer trench
	Ladder Spring (?)	Lincoln	12	26 N.	117½ W.		Not yet dug
	The Rock Slide (?)	Lincoln	16	23 N.	118 W.		Not yet dug

In the latter part of May, R. P. Sheldon, T. M. Cheney, and E. R. Cressman reconnoitered the southern part of the Wyoming range for possible trench sites. During the month of June T. M. Cheney supervised bulldozer operations while R. P. Sheldon, E. R. Cressman, R. A. Smart, and L. D. Carswell assisted by T. K. Rigby described and sampled various localities.

In view of the past phosphate-mining operations in the southern Wyoming range, the present sampling program is directed at evaluation of the phosphate deposits in the area. The field studies, in the absence of analyses, indicate five zones of phosphate within the Phosphoria formation. The lowermost zone occurs at the base of the formation and is about 4 feet thick. Just below the Rex member occurs another phosphate zone consisting of 0.5-foot to 1.0-foot beds of phosphate rock interbedded with mudstone. The third phosphate zone occurs in the lower 50 feet of the Rex member. It consists of interbedded 0.1-foot to 1.0-foot beds of phosphate rock and dolomite. The fourth zone occurs at the base of the upper shale and the fifth at the top of the formation.

At the South Mountain pit the lower phosphate zone is the richest while to the north the phosphate zone at the top of the phosphatic member is the richest.

The other zones were nowhere described as more than a few feet thick.

Correlation studies of the formation were continued. A chert member was described above the upper shale at all localities where that part of the formation was studied. It is probable that this zone correlates with the E



member of the Jackson Hole area. It is also probable that this chert grades into mudstone toward the west to the Coal Canyon area on the basis of key beds of phosphate rock above and below the horizon. This conclusion represents a major change of ideas; previously it was concluded that the E member lensed out above the upper shale going south from the Jackson Hole area.

### Southeast phosphate

Geologic studies  
by J. B. Cathcart

Geologic work in the quarter ending June 30 included studies of the geology, origin, and distribution of the phosphate, uranium in the phosphate products, and the leached zone; correlation of  $Al_2O_3$ ,  $P_2O_5$ , and uranium in the leached zone; stratigraphic studies; and structure studies.

Geology of the Florida land-pebble phosphate deposits, by J. B. Cathcart, L. V. Blade, D. F. Davidson, and K. B. Ketner.

Progress on studies of origin and distribution of the phosphate deposits was reported on in this paper in preparation for the International Geological Congress. The report will probably be expanded in the next quarter as more work is done on these studies. The authors' abstract follows:

"The land-pebble phosphate district is a part of the Gulf Coastal Plain. The phosphate deposits are in strata called the Bone Valley formation and dated Pliocene by most writers. These strata overlie the Miocene Hawthorn formation and are overlain by unconsolidated sands 3 to 20 feet thick.

"The minable phosphate deposits, called matrix in the district, range from a feather edge to about 50 feet in thickness and consist of phosphatic pellets and nodules, quartz sand, and montmorillonitic clay in about equal proportions. The phosphorite particles composed largely of carbonate fluorapatite, range in size from less than 0.105 mm to about 60 cm and in  $P_2O_5$  content from 30 to 36 percent. Locally the matrix displays crossbedding

and horizontal laminations but elsewhere it is structureless. Coarse pebble deposits of moderate  $P_2O_5$  content are found mainly on basement highs and fine pebble deposits of generally higher  $P_2O_5$  content are found on basement lows. Deposits in the northern part of the field contain more pebble of higher  $P_2O_5$  content than those in the southern part.

"The upper part of the phosphatic strata is leached to an advanced degree and consists of quartz sand and clay-sized particles of pseudowavellite and wavellite. The leached zone varies in thickness from a feather edge to 60 feet.

"The origin of the land-pebble deposits is incompletely known. Possible modes of origin are a residuum of Hawthorn age, a reworked residuum of Pliocene age, and a reworked residuum of Quaternary age."

Distribution and origin of uranium in the phosphate products, land-pebble phosphate district, Florida, by W. J. Carr, J. B. Cathcart, and C. H. Gray, Jr.

All assay data on uranium in the phosphate products was synthesized as of February 1952. The report will be transmitted in July as TEM-243. The following is the authors' abstract:

"Over 70,000 samples have been collected from November 1947 to February 1952 in the investigation of the distribution of uranium in the land-pebble phosphate district of Florida. This report presents in map form the results of compiling and plotting the analyses of these samples. Because of the nature of the phosphate products as they are treated by the various companies in the field, and the uranium content of these products, two maps have been prepared, one showing the distribution of uranium in the pebble (44 mesh) fraction of the phosphate deposits, the other showing the distribution of uranium in the concentrate (44 / 150 mesh) fraction of the phosphate deposit.

"The maps show that in general, areas of high uranium content in the pebble correspond to high uranium content in the concentrate. The pebble fraction averages about 0.003 percent higher in uranium than the concentrate."

Future work will attempt to define relations of uranium to size of

particle, to basement "topography", and to stratigraphy.

Distribution of the leached zone of the Bone Valley formation, land-  
pebble phosphate field, Florida, by J. B. Cathcart, W. J. Carr, R. G.  
Petersen, and C. H. Gray, Jr.

Information on distribution of the leached zone was compiled and a report is in preparation. The authors' abstract follows:

"Previous information on the distribution of the leached zone was reported in 1950 and 1951. Since that time, a large amount of new data has been collected, and the maps of distribution have been revised. Three maps, one of thickness, one of radioactivity, and one of grade have been prepared. Data are adequate only on the Peace River area, but sparse data indicate that the drainage areas of the Peace River and Alafia River contain the thickest and best-grade leached zone while the inter-stream divide between them contains thinner and lower-grade material."

Future work will attempt to define the relationships between the leached zone and the present topography, the pre-Pleistocene topography and the Hawthorn topography, as well as stratigraphic relationships and origin.

Correlation of  $Al_2O_3$ ,  $P_2O_5$ , and Uranium, by L. V. Blade.

The object of this study is to find out if there is any relation between these three variables as found in the -200 mesh fraction of the leached zone. Preliminary investigation reveals that the uranium increases with an increase of alumina and phosphorus pentoxide. Further sampling is planned and a report will be written with adequate graphs to show the relationship.

Stratigraphic studies, by J. B. Cathcart and R. G. Petersen.

The objectives of the work were stated in the report for the quarter ending March 31, 1952. As stated in that report, work in comparative stratigraphy has been temporarily recessed. Mine mapping has continued;

the Sydney mine (Hillsborough County, Fla.) was mapped this quarter. Work in the future will be at the Clear Springs mine, and others, as good sections are exposed. A report on the mapping at the Sydney mine will be prepared when samples are treated and analyzed.

The section at the Achan mine is being prepared by Petersen. Heavy-mineral and phosphate separations are almost complete. The Pauway mine section will be screened, washed, and separated next, and other mines will be studied in detail. The final report on these studies will not be made until all mines have been studied.

Report on crystalline wavellite occurrence, by M. H. Bergendahl.

The discovery of unusual spherical aggregates of radiating wavellite crystals on the Royster tract has activated the preparation of a brief report. A complete description, including optical properties, chemical analysis, and the possible significance of this occurrence will be included in the report.

Structural investigations in Polk County, by H. B. Dutro.

The Florida Geological Survey has recently published a structural contour map which establishes a reference datum in the Eocene limestones which underlie the Floridian peninsula. The map is based upon previously unpublished information secured from drill holes in the central and northern parts of the state.

According to the map, the Eocene limestones which underlie Polk County from a homocline which dips southwest at about 12 feet per mile. Superimposed upon the homocline are a number of secondary anticlines and synclines, each of which is reflected by a topographic feature on the present land surface.

A study is being made to determine in what manner and to what degree the folding of the Eocene limestones has affected the attitude of younger

formations, particularly the Bone Valley formation of the land-pebble phosphate field. A report is in preparation, and will be transmitted in the near future.

#### Temporarily recessed projects

The projects on "Relation of the 'topography' of the Hawthorn formation to size of phosphate particles and to topography" has been temporarily recessed until the contour maps on the surface of the Hawthorn formation are complete. This work will be carried on as time permits in the future.

The project on grain-size distribution in surface sands will be continued in the future, as time allows. It was temporarily recessed, due to press of other work.

Work on the relations of uranium and  $P_2O_5$  is being continued as a part of other projects, and will be reported on when enough data are assembled.

#### Mineralogy and petrology by Z. S. Altschuler

##### Southeast phosphate studies

Results of mineralogic and petrologic studies of the Southeast phosphate deposits will be discussed in a report that is now in preparation.

### Northwest phosphate studies

Because of the urgency of the work on the Florida phosphates no work was done during the quarter on the Northwest phosphates nor will any work be done on them in the next quarter. Mr. Owens, who is normally assigned to Northwest phosphates, has been working on the Florida phosphate studies described above.

### Phosphate studies in the Eastern Gulf of Mexico by R. H. Stewart

#### Field work accomplished

During the last quarter 1178 bottom samples, 10 dredge hauls, and 112 sea-water samples were collected from the continental shelf off the west coast of Florida. Most of the samples and dredge hauls were collected from the Venice - Englewood, and Tarpon Springs - St. Petersburg phosphate areas. A few bottom samples and dredge hauls were collected from other parts of the shelf to fill in gaps that existed in previous sampling lines. Sea-water samples were collected from all parts of the shelf between Tarpon Springs and Ft. Myers to obtain data on the distribution of phosphate and uranium in the waters of the area, and its possible relation to the phosphate and uranium in the sediments on the sea floor.

Plans for collection of samples aboard the Alaska in the eastern Gulf and in the Key West area were abandoned because of lack of time and limited availability of marine facilities. Collection of samples (bottom and water) from the upper courses of the Alafia, Manatee, Myakka, and Peace Rivers, and beach samples between Tarpon Springs and Ft. Myers, have been postponed.

#### Results of field work

The additional samples obtained this last quarter have outlined

rather precisely the boundaries of the Tarpon Springs - St. Petersburg and Venice - Englewood phosphate areas.  $P_{25}O_5$  and U analyses of samples from these areas are not yet available, but from visual inspection and qualitative chemical tests they contain an abundance of phosphate. Dredged rock (limestone containing abundant phosphate nodules) from the Tarpon Springs - St. Petersburg area suggests that this may be the source for the unconsolidated phosphatic sediments in this region. Similarly, phosphatic coquina dredged from the Venice - Englewood area suggests that it may be, at least in part, the source of the overlying unconsolidated phosphatic sediments. Samples collected from the Tarpon Springs - St. Petersburg area suggest that there has been some phosphatic replacement of the foraminifera tests found there.

#### Plans

Laboratory examinations of samples - microscopic, physical, chemical - will be continued. Identification and age determinations of the microfauna from samples collected in the Tarpon Springs - St. Petersburg area will be made by O. L. Bandy of the University of Southern California.

## ANALYTICAL METHODS

Spectrography  
by Claude Waring

Work continued during the quarter by Jules Stich on the so-called single-grain method (see TEI-218, p. 33, and quarterly report for 1st quarter of 1952). The wavelengths and sensitivities of all 69 elements have been tabulated. Work was completed to determine the applicability of the Hilger spectrograph to the present method of microanalysis. The tests included a study of the complex spectroproducing minerals carnotite, calcium uranyl vanadate, brannerite, and allanite. The solution method of standardization was applied for the following elements: Ca, K, Na, Fe, Ti, Si, Th, U, V, Ce, La, and Y. No difficulty was found in determining the proper analytical lines, in spite of the low dispersion of the instrument. On the basis of the tests made it is believed that the Hilger instrument can be effectively used for the qualitative analysis of single mineral grains, X-ray spindles, and other microsamples weighing 1 mg or less. A report on the method, "Spectrographic identification of mineral grains," by J. N. Stich, is in process.

Work continued on the application of the Leeds and Northrup microphotometer to automatic scanning of the spectrograms prepared in the semiquantitative method. Progress to date is as follows: The spectra of 68 elements, in six concentrations, have been scanned, the analytical lines located and marked. Many new lines have also been listed and the method will serve as a screening process for better lines. Duplicate card catalogs have been prepared containing information on wave length, and height and width of the lines relative to the element concentration. A Gaertner spectrogram of 1 mg of R. U. powder was traced with the Leeds and Northrup instrument. The lines of 14 elements were detected without difficulty, thus indicating the possibility of automatically scanning spectrograms prepared in the semiquantitative method with prism instruments as well as with grating instruments.



If the automatic scanning technique proves successful, the analytical data provided from many samples will be studied with the idea of converting the rapid semiquantitative method into a more nearly quantitative one. The idea here is to provide a method somewhat analagous to the so-called "Quickie" method of rock analysis recently developed by the Geological Survey (U. S. Geological Survey Circular 165, "Rapid analysis of silicate rocks," by Leonard Shapiro and W. W. Brannock, 1952). Also, if the correct excitation conditions and wavelength lines are chosen, perhaps matrix effects can be eliminated, thus making it possible for one type of standard to be applied to all types of material.

The possibility that thorium can be excited to a higher degree in atmospheres other than air is the subject of an investigation started during the quarter by Jules Stich. If cyanogen bands can be eliminated a greater selection of spectral lines will be available for thorium analysis and perhaps sensitivity for this element can be increased. An Anco gas proportioner has been mounted on the optical bench table of the Gaertner prism spectrograph. Refractory materials will be arced in a quartz gas chamber containing experimental mixtures of oxygen and helium. Elimination of the interfering cyanogen bands will permit inspection of the spectrum from 2000 to 10000 Å for desirable thorium and uranium lines. Tests will also be conducted with other gases.

No work was done during the quarter in the studies by Claude Waring and Helen Worthing of the determination of lead in trace amounts.

The results of the cooperative project by the Chemistry and Spectrography Units on the determination of rare earths in phosphate rocks are reported in "The determination of small amounts of rare earths in phosphate rocks," by Claude Waring and Henry Mela, Jr. (TEI-239, June 1952). The abstract follows:

Rare earths and thorium in phosphatic rock samples are determined by a combined chemical and spectrographic method. After the removal of iron by the extraction of the chloride

with ether, the rare earths and thorium are concentrated by double oxalate precipitation, using calcium as a carrier. The rare earths are freed from calcium by an ammonium hydroxide precipitation with a fixed amount of aluminum as a carrier. The aluminum also serves as an internal standard in the final spectrographic analysis. The method will determine from 0.02 to 2 mg of each rare earth with an error no greater than 10 percent.

Tennyson Myers of the Trace Elements Section Denver Laboratory cooperated during the quarter with H. E. Hawkes of the Geochemical Prospecting Unit on the design of a truck-mounted spectrographic laboratory for field use. Discussions on design and suitable equipment were held in Washington, Denver, and Boston with officials of the Jarrell-Ashe Company. Important applications to the Trace Elements Program are visualized as a likely result of such a mobile unit.

Continued evaluation was made of the quality of the spectrographic analyses both in Washington and Denver by the staff of the Spectrography Unit aided by the staff of the Chemistry Unit. Details of this work will be reported here only when enough data have accumulated to be of more than passing significance.

Results of work in the Denver Laboratory on contamination during grinding are reported in "Contamination of rock samples during grinding as determined spectrographically," by A. T. Myers and Paul Barnett, TEI-179, March 1952. The abstract follows:

Spectrographic analysis was used by the Geological Survey to investigate the kind and degree of contamination resulting from the pulverizing in heavy grinding machinery of three different groups of rock samples: (1) six hard rocks, (2) six unconsolidated sediments, and (3) one massive quartz and one quartzite. It was found that iron can be increased as much as 1.5 percent, nickel 0.006 percent, molybdenum 0.002 percent, chromium 0.001 percent, cobalt 0.002 percent, vanadium 0.001 percent, copper 0.003 percent, and manganese 0.1 percent. The data presented also show there is danger of contamination of samples from grinding on a bucking board.

Radiometry  
by Frank Senftle

Investigation of the thoron method for the analysis of small amounts of thorium continued by Ray Champion during the quarter. With the advent of extremely hot weather in Washington the water for cooling the condenser jacket of the thoron line became too hot and special refrigeration equipment has not yet been obtained. Hence, further work on the standard-type thoron line has been recessed until the equipment is on hand. The apparatus for emanation studies has been completed. The sample is held in a platinum tube heated by an induction furnace, Gas is flowed over the hot sample, picking up the radioactive emanation. It has been found that many ions are produced by heating the gas and hence ion-chamber equipment, similar to that used on the radon lines, cannot be used. Several proportional counters have been constructed to eliminate the necessity of counting ions. Preliminary results on a sample of monazite and one of granite show an exponential increase of emanation with increase in temperature.

Test runs during the quarter by Ray Champion and Jim Bracken with the alpha spectrograph indicated that for best resolution it would be necessary to shape the output pulses. A pulse stretching circuit was built for this purpose, tested, and found to be satisfactory. Some time was spent in decreasing noise and in increasing the linearity of the amplifier circuits and some preliminary work was done on the collimator mechanism. At the end of the quarter the spectrograph was working in principle but many difficulties remain which limit its use as an analytical tool. A great many man hours of research time will be necessary to show concrete results with the instrument and it has been decided to recess the study for the time being because of more pressing work on other projects.

Francis Flanagan and Frank Senftle are investigating the measurement of surface adsorption of different radioactive cations on mineral surfaces. It is hoped that this study will throw some light on the adsorption of radioactive ions on grain surfaces of various minerals. Very little work was done on this project during the quarter. Tests to determine the amount of activated charcoal needed to produce saturation adsorption of bismuth-lead solution were made and a few tests were made to determine the relative adsorption of cesium on the different faces of mineral crystals. Some differences have been noted but no conclusions can yet be drawn.

Aside from the above investigations the bulk of the time of the members of the Radioactivity Unit was spent during the quarter in performing a variety of radiometric analyses on many different types of samples connected with projects in and outside the Section.

A report, "A quantitative radiochemical method for the determination of certain specific sources of natural radioactivity in ores and minerals," by J. N. Rosholt, Jr. was in progress at the end of the quarter. The tentative abstract follows:

The determination of Th, radon, and RaD ( $Pb^{210}$ ) by isolation and subsequent activity analysis of some of their short-lived daughter products is described. The sulfides of bismuth and polonium are precipitated out of solutions of Th- and Ra-bearing ores and the alpha-particle activity of  $Po^{214}$ ,  $Po^{212}$ , and  $Po^{210}$  is measured by scintillation-counting techniques.  $Po^{214}$  activity is used to determine radon,  $Po^{212}$  activity for thorium, and  $Po^{210}$  for RaD.

A continuing program was started during the preceding quarter to check periodically on the radioactivity in the Washington Laboratory. Seven ionization chamber pocket dosimeters were issued to people most likely to receive harmful radiation. These dosimeters are being read and recharged every week and accumulated doseages recorded. Accumulated doseages from March 15 to June 25 for the seven people involved ranged from 36 to 635 milliroentgens.

This is far below the tolerance level of 100 milliroentgens/8 hours.

Further data were compiled during the quarter by Francis Flanagan on standard deviations for the differences between chemical and radiometric uranium analyses of different current lots of Florida phosphate samples and standard deviations are being calculated for previous analyses. These results will be reported when completed.

Chemistry  
by F. S. Grimaldi

Methods of uranium and thorium analysis

In previous reports work in fluorimetry and in methods of uranium and thorium analysis was described under two headings. This work will henceforth be described under the single heading above.

During the quarter a report, "U. S. Geological Survey fluorimetric methods of uranium analysis," by F. S. Grimaldi, Irving May, and Mary H. Fletcher, was issued as TEI-219 (April 1952). This is a manual designed to serve as a guide for analysts interested in the determination of small amounts of uranium. All of the methods presented have been developed in the U. S. Geological Survey and are based on the measurement of the fluorescence of uranium in fluoride melts. These methods have been used for the analysis of almost every material thought to contain uranium. The manual presents a general discussion of the fluorimetric method of uranium analysis, detailed procedures for the analysis of representative materials, and shop drawings of the fluorimeters used in the Survey. The report is now being processed to be distributed as a U. S. Geological Survey Circular so as to achieve the widest possible distribution.

Colorimetric and fluorimetric reagents for the rapid determination of thorium, by Mary H. Fletcher and F. S. Grimaldi

This work consists of investigating a variety of organic compounds as possible reagents for the determination of thorium.

On the basis of previous work in the Washington Laboratory it was thought that the reagent morin would be worthy of consideration. It was tested intensively during the quarter and the effects of reagent concentration, alcohol concentration, and pH on the reactions of morin with thorium and zirconium were studied thoroughly. The reaction was extremely sensitive to any change in the ratio morin/ $\text{ThO}_2$ , to alcohol concentration, and to pH. It would be a very touchy reaction to use for quantitative analysis.

Although the reaction was sensitive to small changes in the amounts of thorium, the lower limit of detection instrumentally was too large. Thus, when more than 10 micrograms of  $\text{ThO}_2$  were present, differences of 0.2 microgram of  $\text{ThO}_2$  could be detected; less than 5 micrograms of  $\text{ThO}_2$ , however, could not be distinguished from the blank. The standard calibration curve was S-shaped. Therefore, morin has been abandoned and other reagents will be tested in the next quarter.

The fluorimetric determination of uranium in saline and nonsaline waters, by Audrey Pietsch and F. S. Grimaldi

A report with the above title was issued during the quarter as TEI-181 (May 1952). The abstract was given in TEI-218, p. 28 (February 1952).

The thiocyanate method for uranium, by Shirley Lundine and Irving May

A study of the thiocyanate method for the determination of uranium was completed during the quarter. A summary of the data and conclusions follows:

1. The color system is unstable and is undesirably sensitive to variations in the concentrations of thiocyanate, stannous chloride, and, to a lesser extent pH.
2. For those conditions in which the variations with concentration of reagents were at a minimum the sensitivity of the reaction was too low.
3. It does not seem likely that, with a reasonable expenditure of time and effort, the deficiencies of the method can be corrected to the point that the method can be used with confidence.
4. It has therefore been decided to discontinue the study. The method does not meet the exacting standards of the Geological Survey.

Studies of critical factors in the fluorimetric determination of uranium, by Mary H. Fletcher

An addendum to the report (TEI-130) of the above title was issued in April 1952. New data on quenching are described. Such factors as the condition, age, and composition of the platinum were used largely determine the amount of platinum going into solution in the melts. The amount of platinum in the melts determines the amount of quenching that occurs and consequently the intensity of the fluorescence. Time-temperature studies indicate that gold is less suitable than platinum as a flux container.

Methods of analysis for other elements and compounds

In this report and in future quarterly reports investigations of analytical methods for elements and compounds other than uranium and thorium will be reported under the above heading.

The determination of micro amounts of  $P_2O_5$  in the presence of As, Si, and Ge, by Harry Levine and F. S. Grimaldi

Work progressed during the quarter on this project leading to the following goals:

1. Establish optimum conditions for the determination of each element in the absence of others by the molybdenum blue procedure. This information is necessary to perform the analyses intelligently.
2. To devise a scheme, if possible, that will allow for the determination of each of these elements in the presence of the others without chemical separations. If this proves to be impractical then the simplest and minimum number of separation techniques will be applied.
3. Some emphasis will also be placed on the determination of micro amounts of phosphorus in sea water.



Experimental work on Goal 1 was completed during the quarter. The vast amount of data collected has to be sorted and studied to determine the best approach to Goal 2. This work will continue in the next quarter.

Investigation of methods for concentration and measurement of lead in sea water and marine deposits, by D. R. Norton

A project is in progress involving the concentration and measurement of lead from sea water and marine deposits, and the preparation of lead iodide from this lead for isotopic analysis.

During the quarter a column of synthetic cation exchange resin was treated with sea water to saturate the column with sea water salts. A sample of sea water containing RaD was then passed through the column. This was followed by wash solutions of sea water, ammonium acetate, and nitric acid. By taking, at intervals, samples for radioactivity measurements, it was possible to follow the exchange of lead and bismuth under these conditions. It was found that most of the bismuth passed directly through the column. Lead was concentrated on the column. Neither lead nor the small amounts of bismuth retained by the column were washed from the column by sea water. The ammonium acetate solution washed most of the lead from the column and the acetic acid solution collected small amounts of bismuth but did not affect the lead. The nitric acid washed all the salts from the column and its activity illustrated that the column retained some lead and bismuth up to this point.

As this method gives a detailed qualitative and semiquantitative picture of the effectiveness of the concentration of lead it will be tried on other types of exchange materials. Experiments were made during the quarter on anion exchange columns but the results have not yet been reported.

Samples of calcareous sediments were examined spectrographically for

lead and other trace elements. In none of these samples was the lead content high enough to enable separation of milligram quantities of lead iodide in a reasonably convenient manner.

A notable concentration of lead has been observed in one of several samples of manganese nodules deposited in Pacific Ocean waters and in the insoluble fraction of a rock-salt sample from Michigan.

Toward the end of the quarter Professor Norton (who has a W.A.E. appointment with the Survey) departed for the field on work not connected with the Survey. He is preparing a summary report on his work with the ion-exchange columns.

The colorimetric determination of total iron with o-phenanthroline:  
a spectrometric study, by Frank Cuttitta

A report with the above title was issued during the quarter as TEI-223 (May 1952). The abstract follows:

A study of the critical factors in the colorimetric determination of total iron in silicate and phosphate rocks, and in other nonmetallic materials is presented. It was desired to ascertain the wavelength of maximum absorbancy, the optimum concentration range for iron, the effect of different substances on the ferrous-o-phenanthroline system, and reproducibility of results. The sample is decomposed with  $\text{HF} \cdot \text{HNO}_3 \cdot \text{HClO}_4$  in platinum, and the iron is determined colorimetrically with o-phenanthroline. No separations are made. Accurate results are obtained on a variety of materials.

A theoretical treatment of the absorption characteristics of the dithizone mixed-color system, by Robert G. Milkey

A report with the above title was issued during the quarter as TEI-236 (May 1952). The abstract follows:

The equation of the standard curves used in the colorimetric determination of trace amounts of metals by dithizone extraction is developed and a further expression is derived which defines the slope of the standard curve.

These equations are used to show the relative effect and importance of the different factors that enter into the construction of the curve. The equations are further utilized to calculate a numerical value for the slope of the standard curve, when lead is the metal determined. When this figure is compared with the slopes of curves determined experimentally the close correlation of values shows that the interfering factors which may be present are not of sufficient importance to affect the analysis.

### Bibliographic Work

During the course of chemical research on methods it is, of course, necessary to do a great amount of systematic bibliographic searching. This systematic searching of the literature often produces bibliographies worthy of distribution to interested workers. Bibliographies currently in preparation in the Trace Elements Section Chemistry Unit, in various stages of completion, are as follows:

1. Annotated bibliography of the analytical chemistry of the rare earths, by Frank Cuttitta.
2. Same for thorium, by Frank Cuttitta.
3. Same for zirconium and hafnium, by Frank Cuttitta.
4. Same for niobium and tantalum, by Frank Cuttitta.

These will be organized into reports for distribution, as time permits.

### Quality Control

A study was made by R. A. Powell on various lots from different sources of  $\text{NaF}$ ,  $\text{Na}_2\text{CO}_3$ , and  $\text{K}_2\text{CO}_3$  available in the stock room. The goal was to find an adequate supply of flux reagents used in the fluorimetric determination of uranium that would give a flux having a high sensitivity and a uniform and low uranium blank.

Thirty-seven different combinations of the above flux components were

tested and blanks were found to vary from 0.0028% to 0.0182% of equivalent uranium per 2 grams of flux. Sixteen combinations gave blanks below 0.004% and are considered adequate for use in measuring small amounts of uranium. The other flux combinations gave blanks too high for use except in the less sensitive, high-uranium ranges where the blank becomes negligible as compared with the uranium of the sample.

This study disclosed that the greatest variability in blanks was caused by the NaF component and suggests that further purification of NaF might give the greatest further reduction in blank. Small variations were caused by the carbonates.

One flux combination gave an apparent low blank, but it also gave a greatly reduced sensitivity which made it less desirable for use in the low range.

Several combinations of flux components gave blanks in the acceptable range. The best flux tested, from the standpoint of both low blank and high sensitivity, was composed of the following:  $\text{Na}_2\text{CO}_3$  -- Mallinckrodt;  $\text{K}_2\text{CO}_3$  -- Eimer and Amend; and NaF -- J. T. Baker.

## GEOCHEMISTRY AND PETROLOGY

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

Arrangements were made during the quarter for Randolph Chapman to begin a cooperative study with the Mineral Deposits Branch of the Survey of the Boulder batholith of Montana. This batholith is probably related to the Idaho batholith and less closely to the California batholiths. It is much smaller than the others and underlies an area of about 2,000 square miles. It is practical, therefore, to study the whole batholith in some detail. This is an unusual opportunity to have a detailed study of the distribution of uranium with relation to petrologic details of a large batholith. Chapman plans to study the distribution of uranium in the individual rock bodies, and the concentration near the borders, in the pegmatites and aplite dikes, and in the adjacent wall rock.

The chemical work done for this project during the last quarter was largely preparatory. Most of the samples submitted are in the low-uranium range and necessitate the use of flux, aluminum nitrate, and other reagents having extremely low uranium blanks. Consequently, an extensive testing program has been carried out on all available flux components and a large batch of low-blank flux is being prepared. Aluminum nitrate is being purified by extraction and various mineral acids redistilled to lower their uranium content.

Early in the next quarter uranium analyses will start on the large number of samples which have been submitted. At the present time two chemists, Frank Cuttitta and Glen Edgington, are assigned to work on this project full time and one chemist, Charles A. Kinser, is assigned to work on this project half time.

Three of the petrologists in the group, Larsen, Smith, and Gottfried spent about seven weeks during the quarter in southern California, partly in conference with Prof. Harrison Brown and his group at California Institute of Technology and partly in the field. We made some collections from the southern California batholith, especially from the eastern part of the main batholith, and partly from the disconnected granite bodies east of the main batholith. This should enable us to compare the three zones in the batholith.

We also made some reconnaissance collections from the southern part of the Sierra Nevada batholith. In the laboratory we have prepared type rock sets from the California batholith, the Idaho batholith, and the San Juan lavas. We have also separated the minerals from a number of rocks for a study of the rare elements in the minerals. The chemists plan to begin active work on this material soon. As the results come in we should be able to make some comparisons between the different groups of rocks. The data we now have indicate that the Idaho rocks are very low in uranium, the California rocks higher, the lavas of the San Juan Mountains, Colo., still higher, and those from the Carboniferous rocks of New England the highest. No thorium determinations are available but the high content of monazite and allanite in the Idaho rocks indicates that they are high in thorium.

Synthesis of uranium-bearing minerals  
by Irving Friedman and George J. Jansen

Work on mineral synthesis at room temperature and atmospheric pressure continued during the quarter.

As table 3. shows, work on the uranite group continued with two synthetics from the previous quarter more definitely confirmed and two additional

Table 3.--Data on synthetic minerals

<u>Mineral</u>	<u>Method</u>	<u>Powder pattern</u>	<u>Electron micro. exam.</u>	<u>Remarks</u>
Parsonite	Beintema (1938) 1/	Spacings slightly different than standard	Particle shape, size, density, same as other members of uranite group	Synthetic preparation probably differs in hydration state from standard.
Autunite	Beintema (1938) 1/	Autunite	do	Confirmation and rerun of autunite prepared in previous quarter.
Saléeite	Beintema (1938) 1/	Saléeite	do	Prepared by method for uranocircite in Beintema ('38).
Fritzscheite	Beintema (1938) 1/	Member of uranite group 2/	do	Do
U. molybdate	Stoichiometric mixture	Identical to U molybdate unknown	None	Spectrograph analysis of X-ray unknown showed major U and Mo. Synth. pattern identical.
Fe vanadate	Brandt (1943) 2/	Not pattern for Fe <sub>2</sub> O <sub>3</sub> or V <sub>2</sub> O <sub>5</sub> . Standard lacking	None	Lacking standard, positive identification is impossible at present.
Tyuyamunite	Stoichiometric mixture	Pattern identical with NH <sub>4</sub> carnotite	None	Attempts to base exchange Ca <sup>++</sup> for NH <sub>4</sub> <sup>+</sup> unsuccessful.
Tyuyamunite	Fusion of constituents	Pattern not identical with standard for tyuyamunite	None	Procedural error responsible for failure of synthesis.
Rauvite	Stoichiometric addition of V <sub>2</sub> O <sub>5</sub> to synth. tyuyamunite	Pattern not identical with standard for rauvite	None	Synthetic starting material was NH <sub>4</sub> <sup>+</sup> carnotite on which base exchange by Ca <sup>++</sup> was attempted. When pattern was found not identical with rauvite, synthetic material was rechecked and failure of base exchange was seen to be responsible.

- 1/ Beintema (1938) Rec. Trav. Ch. N. Pays-Bas 57, 115-75  
 2/ Brandt (1943) Arkiv Kem. Min. Geol. 17, 6 p 3  
 3/ Frondel, J. W. (Private communication)

members synthesized. Saleeite had resisted previous efforts at synthesis by a method analogous to that used for autunite but was finally synthesized by a procedure analogous to that used for uranocircite in the previous quarter. Fritzscheite, the manganese uranite, had been reported in Frondel and Fleischer 1/ as of doubtful composition. Using the method for uranocircite a product was obtained which gave a pattern structurally similar to the other members of the group. Semiquantitative spectrographic analysis, as shown in table 4, indicates that the components present are those desired. It is hoped that this synthesis may contribute to establishing the validity of the species.

As indicated in the table, work began on the vanadates during the quarter. Attempts were made to synthesize tyuyamunite, rauvite, and  $\text{FeVO}_4$ . Only the  $\text{FeVO}_4$  appears to have been made. Physical appearance and powder pattern differ from  $\text{Fe}_2\text{O}_3$  and from  $\text{V}_2\text{O}_5$ , the two components. Lack of an X-ray standard prevents positive identification.

Electron photomicrographs were made of the several members of the uranite group and zippeite, under the direction of E. J. Dwornik. These micrographs were helpful in identification by indicating particle size, shape, density, and homogeneity of the products.

Optical examination of products of synthesis was limited, by the fineness of the particles, to establishment of index range and anisotropy.

As a final check and aid in identification, some of the synthetics were analyzed by the semiquantitative spectrographic method. These analyses were done by C. S. Annell.

Low temperature-atmospheric pressure work will continue in the next quarter with greater emphasis on the vanadates. Attempts have been made,

1/ Frondel and Fleischer, (1950), A Glossary of Uranium-and Thorium bearing minerals. U. S. Geological Survey Circular 74 (1950).



Table 4.—Spectrographic analyses of synthetic minerals

Mineral	Composition	Spectrographic analysis (Percent)			
		Over 10	1-10	0.1-1.0	0.01-0.1
Torbernite	$\text{Cu}(\text{UO}_2)_2(\text{PO}_4)_2 \cdot 8-12\text{H}_2\text{O}$ (Dana 1951)	U	Cu, P		Si
Bassetite	$\text{Fe}(\text{UO}_2)_2(\text{PO}_4)_2 \cdot 8\text{H}_2\text{O}$ (Fron del and Fleischer 1950)	U	P, Fe	Si	
Uranocircite	$\text{Ba}(\text{UO}_2)_2(\text{PO}_4)_2 \cdot 2\text{H}_2\text{O}$ (Dana 1951)	U, Ba	P		Si
Parsonsite	$\text{Pb}_2(\text{UO}_2)(\text{PO}_4)_2 \cdot 2\text{H}_2\text{O}$ (Fron del and Fleischer 1950)	U, Pb	P	Si	
Uranospinite	$\text{Ca}(\text{UO}_2)(\text{AsO}_4)_2 \cdot 8\text{H}_2\text{O}$ (Dana 1951)	U, As	Ca	Si	
Fritzscheite	$\text{Mn}(\text{UO}_2)_2[\text{P}, \text{V}]\text{O}_4]_2 \cdot 8\text{H}_2\text{O}?$ (Fron del and Fleischer 1950)	U	P, Mn		Si

Analyst: C. S. Annell

using Morey-type bombs, to grow larger crystals from synthetics so that optical examination may be done. Data on this work are insufficient to report on in this quarter. This work will also continue in the next quarter.

High temperature-pressure work is in the planning stage pending arrival of equipment on order or under construction.

#### X-ray diffraction studies by Charles Christ

Plans for X-ray diffraction studies are now crystallized as to the type of work to be done on the project. As a result, certain important problems have been outlined and are being attacked.

#### Present investigations

Three main activities are being pursued: (1) crystal structures and crystal chemistry of vanadate minerals; (2) crystal structures of rare-earth carbonates; (3) instrumentation for crystal-structure analysis.

#### Vanadate minerals

The association of vanadate minerals with uranium deposits constitutes an interesting and challenging problem. There is, however, a considerable dearth of knowledge concerning the crystal chemistry of vanadium in general, and in particular that of vanadium minerals. As a result of the field studies in the Colorado Plateau a large number of vanadium minerals have been collected by Alice Weeks for detailed laboratory study. We have begun work on several of these. H. T. Evans now has under investigation the following: (1) montroseite, (2) melanovanadite, (3) hummerite, (4) two polymorphic forms of artificial

KVO<sub>3</sub>.

Montroseite.--Using material supplied by Alice Weeks, Evans has shown that montroseite gives on the same X-ray pattern three sets of reflections corresponding to three distinct orthorhombic forms. One set of reflections is sharp, the other two diffuse. This corresponds to three phases intergrown in parallel orientation, i.e. in syntaxic intergrowth. The cell dimensions are:

	<u>a<sub>0</sub> (A)</u>	<u>b<sub>0</sub> (A)</u>	<u>c<sub>0</sub> (A)</u>	<u>V (A<sup>3</sup>)</u>
Sharp	4.54	9.97	3.03	136.9
Diffuse	4.80	9.63	2.93	135.4
Diffuse	4.89	9.39	2.93	134.4

Space Group: Pbn

Considering that the volume occupied per oxygen ion must be of the order of 17 A<sup>3</sup>, it follows that the unit cell of montroseite contains 8 oxygens, and this fact imposes definite limitations on the chemical formula. In particular the formula 2 FeO · V<sub>2</sub>O<sub>3</sub> · 7 V<sub>2</sub>O<sub>4</sub> · 4 H<sub>2</sub>O (Weeks, Cisney, and Sherwood, Am. Mineral. 36, 327 (1951)) cannot be correct. This formula probably resulted from analyses on impure material. It appears that there is no material particularly suitable for analysis and that the most effective way of getting at the formula will be through the determination of the crystal structure. Since the c<sub>0</sub> of montroseite is only 2.9 A, it would seem that it will not be a difficult task to analyze this structure and this is being done. It will be necessary to study other specimens of montroseites in order to determine whether the syntaxy encountered in the present material is characteristic.

Melanovanadite.--Patterns prepared by Evans from specimens of this mineral show sharp and diffuse reflections arising from the same tri-

clinic (pseudomonoclinic) lattice (in contrast to montroseite). Barnes and Quarashi in *Am. Mineral.* 37, 416 (1952) report unit-cell dimensions for melanovanadite which do not take into account these diffuse reflections. Evans has suspended work on this mineral until the problem can be discussed with them.

Artificial potassium vanadates.—Evans has previously, elsewhere, made some preliminary study of the behavior of vanadium pentoxide solutions at various pH ranges, and prepared a series of potassium salts of complex vanadates. Two of the compounds have been selected for further study. Chemical analyses have shown these to be polymorphs of the same formula  $KVO_3$ . It is planned to study the crystal structures of these.

Hummerite.—Work has just begun on this mineral.

Since W. H. Barnes and his group at the National Research Council, Ottawa, Canada are very actively engaged in a study of vanadium minerals (*loc. cit.*), it will be necessary to maintain close contact with them in order to avoid duplication of effort. Through correspondence, chiefly by Mrs. Weeks, we know already fairly well what this group is now working on and what they are planning to work on. However, in order to arrive at a firm basis for collaboration in the future, Evans is planning to accept Mr. Barnes' invitation to visit and confer with him at Ottawa.

#### Rare-earth carbonates

As a natural outgrowth of the work of Howard Jaffe on the thorium-bearing ore body discovered in California, certain fundamental crystallographic problems have arisen. One of these is the structural nature of

the rare-earth carbonates in the parisite - synchisite series. This problem is being investigated on the X-ray side by Gabrielle Donnay with the active participation of H. T. Evans, and by Howard Jaffe on the mineralogic-petrographic side. Suites of minerals have been obtained from Harvard University and from the National Museum. Mrs. Donnay's studies on a number of crystals of the parisite type from various localities have shown that these consist mainly of intergrowths of a number of different hexagonal phases in parallel orientation. Five different phases have been distinguished so far, all based on the same subunit having  $c_0 = 4.9$  Å, with the true  $c_0$  approximately:  $2c_0$  (bastnaesite);  $4c_0$  (synchisite?);  $6c_0$  (parisite);  $9c_0$  (new);  $6c_0$  (rhombohedral, new). The prevalence of intergrowth among these crystals makes analytical data of questionable value. A few crystals of apparently one type each have been isolated for chemical and optical measurement. The previously accepted chemical picture is summarized in Dana, 7th Ed., and the X-ray work of Oftedal (Zeit. f. Krist. 78, 462 (1931)) provided the structural picture. On the basis of the present work it is apparent that the whole picture will undergo considerable revision.

Mrs. Donnay is planning to present a paper at the November 1952 meeting of the Mineralogical Society of America on the results obtained to date. This investigation is continuing.

It is interesting to note that the X-ray work on the parisite-synchisite series is a natural continuation of previous work by Mrs. Donnay and J. D. H. Donnay on the andorite-sundite series. Here also is a problem in syntaxial intergrowth. There are two polytypic forms, observed both as intergrowths and separately, with a common pseudoperiod

$c_0 = 4.3$  Å. These are designated andorite IV ( $c_0 = 4c_0$ ) and andorite VI ( $c_0 = 6c_0$ ). Ramdohrite (andorite) is discredited. The existence of an "andorite XII" announced by Nuffield, Trans. Royal Soc. Canada (3) Sr. IV, 34, 41 (1945) is disproved. A paper on this subject was presented at the June 1952 meeting of the American Crystallographic Association.

The new rare-earth carbonate "sahamalite" discovered by Jaffe has been studied by Evans. It is monoclinic,  $P 2_1/a$ , with  $a_0 = 5.92$  Å;  $b_0 = 16.21$  Å;  $c_0 = 4.632$  Å;  $\beta = 116^\circ 45'$ . The density calculated from the cell contents  $Ce_2 (Mg_{.85} Fe_{.15}) (CO_3)_4$  is 4.30, identical with the measured value. Further work is being carried on to determine optical orientation and morphology.

#### Instrumentation for crystal-structure analysis

IBM equipment.—A memorandum was prepared on May 16, 1952 by H. T. Evans outlining the nature of the calculations involved in crystal-structure analysis and describing the use of IBM techniques for making these calculations. It has been agreed that the Survey will add a calculating punch-type 602A to the existing equipment of the IBM unit. With this equipment available, it will be possible to make many types of computations necessary to the work of this project, which would be too lengthy and involved to do in any other way open to us. With IBM equipment it is possible to make calculations of a kind not possible with our projected analog computer (discussed below) which is designed only for computing electron density and similar vector maps.

With this equipment available it will be possible, among other things, to prepare a number of tables needed by us and by diffraction

workers in general. These will not be described here, but will be reported upon as the work proceeds.

Analog computer.--A good deal of thought and discussion has been expended on the design of an analog computer for the calculation of electron density and Patterson maps. As originally planned, the construction of this will be based on the design of McLachlan and co-workers (Rev. Sci. Instr. 21, 779 (1950)). We have, however, discovered several modifications of the McLachlan scheme. Among these is a method for reducing the number of selsyn motors used, by a factor of approximately 2. Since the large number of motors needed determines the principal cost of the calculator, this is an important discovery. It has also been possible to work out a method for making the calculator completely automatic so that having set the data into the machine, a printed contour map can be obtained without further attention from the operator. Invitations for bids for the selsyn motors have been issued. When the motors are at hand we will proceed with the construction of the calculator.

#### Other activities

Aside from the main lines of investigation described above, several other important projects have been started. Among these is a theoretical study, by Evans, of the question of the undeterminacies of polar crystal structures. For certain structures (e.g.,  $\text{BaTiO}_3$ ) the temperature and structure parameters which define the structure of the crystal can be varied mutually over a considerable range without affecting the quality of match of the observed and calculated intensities, the ultimate criterion upon which all crystal-structure determinations are based. The

extent to which this circumstance interferes with crystal-structure analysis in general is being investigated.

Mrs. Donmay has continued preparation of several reports on the X-ray powder diffraction methods. There will be three divisions considered: (a) identification of minerals from powder patterns; (b) interpretation of powder patterns for minerals whose cell dimensions are unknown, and for which there is no standard pattern; (c) precision determination of lattice constants from charts obtained with the high-angle Geiger counter X-ray spectrometer. This particular project was started at the suggestion of Charles Christ in order to obtain for our own use as much as possible of the experience gained by Mrs. Donmay on her work on feldspars at the Geophysical Laboratory.

#### Future work

The nature of the work continuing the present projects has been indicated. In addition some thought is being given to the need for structural knowledge of the vanadates of uranium, and other compounds of uranium. The problem of the structure of carbonate apatite and of the mode of association of uranium with apatite is under consideration. It is absolutely necessary that some of these problems and especially the carbonate apatite one be approached by synthesizing appropriate study materials; the need is very definite for close collaboration among the field geologist, the chemist, the mineralogist, and the crystallographer.

#### Isotope geology

##### Radioactive elements and their decay products

Isotope geology of the Colorado Plateau ores, by Lorin Stieff and Thomas Stern



Lorin Stieff and Frank Senftle attended during the quarter a classified conference on mass spectroscopy at Oak Ridge, Tenn. Lorin Stieff (with other members of the Geological Survey) attended a symposium on the mineralogy of uranium deposits in the New York offices of the Division of Raw Materials, AEC.

Because of the need of more mass spectrometric analyses the mass spectrometry program has been expanded and reorganized. Lorin Stieff has been put in charge of coordinating and expediting the work being conducted on the instrument now under construction. The electronic components are nearly finished and it is expected that initial tests can be made by October 1.

Irving Friedman has joined the staff and will help Stieff on the mass spectrometer until the instrument is operating. Parts for a second spectrometer to operate in the light mass range have been ordered. Friedman expects to complete construction on this instrument by December, and it will be used for various problems in the light mass range.

In conjunction with the mass-spectrometer program, it has been proposed to set up a number of lead-isotope standards to intercalibrate the age work being conducted in the various laboratories. This problem is very real as is evidenced by the variations in isotope analyses of a given sample by different investigators. It has been discussed at some length with the National Bureau of Standards and also with a number of other laboratories doing mass-spectrographic analyses. It is our intention to initiate an isotope-standard program by preparing a lead standard that can be analyzed by other investigators. The main purpose of such a standard will be to correlate the age results of these laboratories. No work can be done on this project, however, until the mass-spectro-

meter program is well under way.

The report "A preliminary determination of the age of some Colorado Plateau uranium ores by the lead-uranium methods," by Lorin Stieff and Thomas Stern has been rewritten prior to final editing. An abstract, "The lead-uranium ages of some uraninites from Triassic and Jurassic sediments of the Colorado Plateau," by Lorin Stieff and Thomas Stern, has been prepared for presentation at the November meeting of the Geological Society of America in Boston. The abstract follows:

In a study on the origin of the uranium deposits in the Triassic and Jurassic sediments of the Colorado Plateau, 13 uraninites from 9 deposits were collected for  $Pb^{206}/U^{238}$  and  $Pb^{207}/U^{235}$  age determinations. These uraninites are believed to be the best of more than 100 samples from the Plateau on which age determinations have been made. The 13 uraninites have a mean  $Pb^{206}/U^{238}$  age of approximately 70 million years when corrected only for common lead.

Chemical and mass spectrometric errors change the mean  $Pb^{206}/U^{238}$  age by approximately  $\pm 4$  million years. Uncertainties resulting from the common lead corrections and the possible presence of old radiogenic lead in the ores will decrease the mean  $Pb^{206}/U^{238}$  age by approximately 3 million years. Corrections for the selective loss of uranium will decrease the mean age, whereas selective loss of daughter products will increase the mean age by approximately 10 million years.

Holmes gives 130 and 160 million years as the close of the Jurassic and Triassic periods, respectively. If the ages calculated for the uraninites are close to the true ages of the ores, then the uranium was probably introduced into the sediments in late Mesozoic or early Tertiary time (60 - 70 million years). This conclusion differs markedly from earlier conclusions that the uranium ores were formed in the Triassic and Jurassic sediments of the Colorado Plateau during or soon after the deposition of the rocks.

Fourteen samples have been sent to Mr. J. J. Katz, Argonne National Laboratory, for quantitative oxygen determinations and for  $O^{16}/O^{18}$  temperature studies. Approximately  $2\frac{1}{2}$  man months were spent in the preparation of this group of samples. The group includes eight pegmatitic uraninites, uraninite from Happy Jack mine, Utah, two synthetic uranin-

ites, and a synthetic fourmarierite prepared by Professor John Gruner of the University of Minnesota, a very pure calcium uranyl vanadate (tyuyamunite) from the Small Spot mine, Colo., and a specimen collected from La Sal No. 2 mine, Colo. of an unidentified uranium mineral. Also, two uraninite samples from the Colorado Plateau have been sent to Professor Patrick Hurley of M. I. T. for helium determinations.

Carefully purified heavy-liquid separates of two new minerals from La Sal No. 2 mine, first noted in October 1951, one with a tetragonal structure similar to zircon but containing mostly oxides of uranium and the other a vanadium-bearing mineral, have been prepared. Preliminary chemical analyses of these two minerals are as follows:

	Uranium mineral*		Vanadium mineral
	Sample No. TWS/57/51		Sample No. TWS/58/51
UO <sub>2</sub>	52.93	V <sub>2</sub> O <sub>4</sub>	68.53
UO <sub>3</sub>	17.38	V <sub>2</sub> O <sub>3</sub>	10.30
SiO	5.20	FeO	3.53
As <sub>2</sub> O <sub>5</sub>	4.35	UO <sub>2</sub>	1.34
Al <sub>2</sub> O <sub>3</sub>	3.87	UO <sub>3</sub>	3.47
V <sub>2</sub> O <sub>5</sub>	2.85	As <sub>2</sub> O <sub>3</sub>	0.73
P <sub>2</sub> O <sub>5</sub>	2.45**	SiO <sub>2</sub>	2.04
Fe <sub>2</sub> O <sub>3</sub>	1.24	MgO	1.12
S	0.93***	Al <sub>2</sub> O <sub>3</sub>	2.46
Pb	0.12	-H <sub>2</sub> O	0.48
Loss at 110C	1.68	+H <sub>2</sub> O	4.72***
Loss at 110-450 C	6.81		
Loss at 450-800 C	<u>nil</u>		
Total	99.81		98.72

\* The actual valences for most of the elements in this material are not known but were assumed for purposes of calculation.

\*\* Analyses on second fraction of material (numbered TWS/57A/51).

\*\*\* On ignition at 110-250C some organic material also lost. This, added to +H<sub>2</sub>O, totals 6.98 percent.

Twenty-one Plateau uranium ores have been prepared for age studies during the quarter and submitted for chemical analysis and preparation of the

lead iodides. This group of ores includes eight uraninites, ten non-carnotite-bearing ores (primary ores), and three carnotite ores. In addition, six galenas from the Plateau were prepared and submitted for analysis. Isotopic analyses of eight lead iodides were received from Oak Ridge.

The report, "Preparation of nuclear-track plates and stripping films for the study of radioactive minerals", by L. R. Stieff and T. W. Stern (TEI - 127) was published in the *American Mineralogist*, vol. 37, pp. 184-196, March-April 1952. The report, "Identification and lead-uranium ages of massive uraninites from the Shinarump conglomerate," by L. R. Stieff and T. W. Stern (TEM - 317) was published in *Science*, vol. 115, pp. 706-708, June 27, 1952.

Age determination by the zircon-X-ray method, by F. E. Senftle

In the Trace Elements work plan and operating budget, fiscal year 1953, p. 135, a project entitled "Age determinations by potassium-argon method" was proposed. This work was to be conducted by Professor P. M. Hurley at M. I. T. on a W. A. E. basis. Since this proposal, however, Professor Hurley has devised an X-ray method for age determination of zircon which appears to have merit, and which ties in with the other projects of the Survey. For these reasons and also since the potassium-argon method is still in an embryonic stage, it has been decided to sponsor work on the zircon method instead of the potassium-argon method. This work has just begun and a more detailed discussion will be left until the next report.

Isotope geology of lead, by R. S. Cannon, Jr.

Long-range objectives are to investigate the geochemical significance of variations in the isotopic constitution of lead in rocks, minerals, meteorites, and ores; and to apply this method of geochemical interpretation to better understanding the origin and occurrence of ores of metals, to improving exploration techniques for the discovery of ores, and to solving a variety of fundamental problems of geology and cosmogony. Immediate objectives include empirical studies of geologic variations as guides to selection and preparation of samples, evaluation of laboratory methods and measurements in isotopic analysis of lead, and determining the isotopic composition of primeval lead; of lead in sea water, and of lead in magmas.

The work that has been carried forward by Geological Survey scientists during the past 12 months on these problems has been largely preparatory in nature, paving the way for more rapid accumulation of data and conclusions during the next year. In addition to Survey contributions, the Mass Assay Laboratory at Y-12, Oak Ridge, has provided all lead isotope analyses for

this project to date. Also, during this quarter arrangements have been perfected with Professor Harrison Brown and his colleagues in the geochemical laboratories now being constructed at California Institute of Technology for collaborating in a joint attack on many of these problems. In this cooperative research isotope dilution and radiometric techniques of analysis will be used to study, especially in ordinary rocks containing low concentrations of lead and uranium, isotopic variations of lead, radioelement age measurements, and geochemical distribution of lead, uranium, and associated elements.

During this quarter geologic planning has been devoted mostly to defining problems and to planning selection and procurement of sample materials best suited for the cooperative research program with the CIT group. Attention has been given especially to very old rocks and minerals, to marine chemical sediments of all ages, and to very young volcanic rocks. In the field, potential sources of sample materials have been examined, and more than 50 additional samples of limestones, volcanic rocks, and sulfide ores for isotope investigations have been collected in South Dakota, Colorado, Arizona, and California. In addition, about a dozen rock-forming minerals have been collected in relatively pure concentrations for laboratory use as mineral reagents. The suitability of sample materials collected must be tested further in the laboratory; during this quarter preliminary chemical testing has been done on more than 30 samples and a number of thin and polished sections have been prepared for petrographic examination.

Several types of marine materials on which chemical investigations are in progress include calcareous sediments and skeletons, manganese nodules, and rock salt. The traces of lead in rock salt of Silurian age from New York State are not in the crystal structure of the halite but are associated with the water-insoluble particles in the sample. This finding may be

correlated with an earlier discovery that traces of lead in modern sea water seem to be in suspension rather than in solution.

In a variety of samples of modern marine calcareous sediments and skeletons of marine organisms lead appears to be present in concentrations of only a few ppm. Low concentrations of lead have likewise been found in manganiferous nodules or concretions from marine sedimentary rocks of Cretaceous age in South Dakota and of Pennsylvanian age in Pennsylvania, whereas a modern marine manganese nodule from Sylvania Guyot in the Pacific is found to contain much greater concentrations of lead, on the order of 1000 ppm.

Lead isotope analyses obtained during the quarter include 5 analyses of commercial galena concentrates from concentrating mills in lead-mining districts of the western United States. These are composite samples, each representing a large tonnage of lead ore. Three samples are from 3 mills serving 3 different mines in the Metaline mining region of northeastern Washington and southern British Columbia. These three analyses are similar in characteristics to one another and to Nier's analysis No. 9 of galena from Metaline Falls, Wash. The other 2 samples represent lead ore deposits in the pre-Cambrian rocks of Yavapai County, Ariz. The analyses of this pair of samples likewise are rather similar to each other and resemble several of Nier's analyses of galena from ore deposits of pre-Cambrian age from other regions. These results will be used as part of the data needed to test the uniformity or variability of lead isotope ratios within these 2 mining regions.

Plans for next quarter include considerable field work, chiefly to collect suites of recent volcanic rocks and marine limestones of diverse age. Several hundred additional samples will be collected during the summer field

season. Little or no petrographic work will be possible during this period, but chemical testing will be done on a large number of potential sample materials. Additional samples of lead iodide will be prepared for lead isotope analysis, including samples of lead from the oceans. During the quarter additional work will be done toward preparing reports on the nature of ore-lead and on isotope variations in a crystal of galena from Joplin, Mo.



## MINERALOGY AND PETROGRAPHY

Properties of uranium-bearing minerals  
by J. C. Rabbitt

Work progressed during the quarter on the monograph, "Mineralogy of Uranium" under the editorship of Rabbitt. Clifford Frondel of Harvard University, who has a W.A.E. appointment with the Geological Survey is writing the chapter on description of properties; Judith Frondel is preparing descriptive tables; George Switzer of the National Museum is writing chapters on the occurrence and association and the geographic location of the minerals; Theodore Botinelly is writing a chapter on characteristic methods of identifying uranium minerals in the field and laboratory. It is expected now that the writing part of the job will be finished by early fall.

During the quarter analytical work was completed by Frank Cuttitta on pure samples of curite, ianthinite, billietite, and orange schoepite. Also, chemical analyses by Alexander Sherwood, X-ray work by Joseph Berman, and spectrographic analyses by Jules Stich were reported for samples of the uranium silicates kasolite, uranophane, cuprosklodowskite, soddyite, sklodowskite, and beta-uranotil, for D. H. Gorman of the University of Toronto. The results of this analytical work will be included in the monograph.

Judith Frondel has been investigating the hydrous uranium oxides. During the quarter she added to data on hand on various properties (optical constants, unit-cell constants, chemical analyses, dehydration curves, X-ray spacings) on pure specimens of becquerelite, billietite, schoepite, paraschoepite, vandendriesscheite, ianthinite, masuryite, mineral "X". An abstract, "Billietite and becquerelite," by Judith W. Frondel and Frank Cuttitta, has been prepared for presentation at the G.S.A. meeting in

Boston in November. The abstract follows:

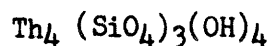
Billietite ( $\text{BaO} \cdot 6\text{UO}_3 \cdot \text{H}_2\text{O}$ ), originally described from Katanga by Vaes (1949), is a valid mineral species isostructural with becquerelite ( $"2\text{UO}_3 \cdot 3\text{H}_2\text{O}"$ ). New chemical analyses and Weissenberg X-ray studies on two specimens of billietite from Katanga gave (1)  $a_0 = 12.04\text{\AA}$ ,  $b_0 = 14.25\text{\AA}$ ,  $c_0 = 15.06\text{\AA}$ ;  $n_X = 1.730$ ,  $n_Y = 1.810$ ,  $n_Z = 1.815$ ;  $\text{BaO} = 6.88$ ,  $\text{UO}_3 = 82.76$ ,  $\text{H}_2\text{O} = 8.97$ ,  $\text{SiO}_2 = 0.76$ ,  $\text{CaO} = 0.30$ , total = 99.76; S.G. = 5.57 (meas.), 5.33 (calc.); (2)  $a_0 = 12.08\text{\AA}$ ,  $b_0 = 13.98\text{\AA}$ ,  $c_0 = 15.06$ ;  $n_X = 1.725$ ,  $n_Y = 1.780$ ,  $n_Z = 1.790$ ;  $\text{BaO} = 7.41$ ,  $\text{UO}_3 = 84.39$ ,  $\text{H}_2\text{O} = 8.68$ , total 100.48; S.G. = 5.15 (meas.), 5.40 (calc.). Billietite is orthorhombic,  $2V(-) \sim 35^\circ$ ; X pale yellow, Y and Z deep golden yellow. There are 4 ( $\text{BaO} \cdot 6\text{UO}_3 \cdot 11\text{H}_2\text{O}$ ) per unit cell. The unit cell differs from that of Brasseur (1949) in that a- and b- axes are interchanged and the b-axis is doubled. Brasseur has  $a_0 = 7.11\text{\AA}$ ,  $b_0 = 12.08$ ,  $c_0 = 15.09$ ;  $n_X = 1.730$ ,  $n_Y = 1.822$ ,  $n_Z = 1.829$ ;  $\text{BaO} = 6.95$ ,  $\text{UO}_3 = 83.86$ , ign. loss 10.49, total = 101.30.

A new analysis and X-ray study of becquerelite from Katanga gave  $a_0 = 12.45\text{\AA}$ ,  $b_0 = 13.92\text{\AA}$ ,  $c_0 = 15.09\text{\AA}$ ;  $n_X = 1.770$ ,  $n_Y = 1.805$ ,  $n_Z = 1.820$ ;  $\text{UO}_3 = 89.53$ ,  $\text{H}_2\text{O} = 8.95$ ,  $\text{SiO}_2 = 1.82$ , total = 100.30; S.G. = 5.3 (meas.), 5.56 (calc.). Becquerelite is orthorhombic,  $2V(-) \sim 30^\circ$ ; X yellow, Y and Z deep golden yellow. There are 14 ( $2\text{UO}_3 \cdot 3\text{H}_2\text{O}$ ) in the unit cell.

The near coincidence in dimensions and intensities of the single crystal and powder X-ray photographs of billietite and becquerelite indicate that these minerals are isostructural. From the new analysis a formula ( $7\text{UO}_3 \cdot 11\text{H}_2\text{O}$ , with S.G. calc. = 5.60) for becquerelite can be written analogous to that of billietite. The unit cell contains four formula units. A substitution of one Ba for one  $\text{U}^6$  is presumed. If the role of water in the structure were understood it might be possible to explain the necessary valence compensation for such a substitution by the O to (OH) ratio in each mineral.

Results of a study by Clifford Frondel by X-ray and optical methods and, in part, by thermal analysis, indicate that the following minerals are identical: thorogummite (including nicolayite) from the four known localities, Texas, Pennsylvania, Australia, Japan; maitlandite; hyblite; and mackintoshite. The X-ray patterns of these minerals can be completely indexed in terms of a tetragonal cell with the space group and virtually the same cell dimensions as thorite. All of the substances are approximate in composition to a hydrated thorite, usually with much U, Pb, and rare earths in substitution for Th, although with (Th, etc.)  $\text{O}_2$ :  $\text{SiO}_2$  slightly greater than 1:1. Thorogummite, et al., seem from the available evidence to be either secondary nonmetamict thorite or, more probably, to be a

hydroxyl-substituted silicate, isostructural with thorite, with the formula and unit contents:



The latter interpretation is indicated by the thermal study. A series may exist to thorite, analogous to the grossularite-calcium aluminate series. A report on this work is in preparation.

The second revised edition of "A glossary of uranium- and thorium-bearing minerals," by Judith Weiss Frondel and Michael Fleischer was published during the quarter as U. S. Geological Survey Circular 194. The circular is available free on application to the Geological Survey.