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TRACE ELEMENTS RESEARCH QUARTERLY PROGRESS REPORT– JANUARY 1 TO MARCH 31, 1952

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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.

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Technical Information Service, Oak Ridge, Tennessee

GEOLOGY AND MINERALOGY

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TRACE ELEMENTS RESEARCH QUARTERLY PROGRESS REPORT*

JANUARY 1 TO MARCH 31, 1952

ABSTRACT AND SUMMARY

Colorado Plateau geologic studies

Investigations of uranium deposits in sandstones of the Colorado Plateau were continued during this quarter. Studies of past and present ground-water conditions on the Colorado Plateau suggest that the most favorable time for the accumulation and concentration of ore-bearing ground-water solutions was during the period after deposition of the Salt Wash sandstone member of the Morrison formation of Jurassic age and before deformation in early Tertiary time. On the other hand, age determinations indicate that the ore-bodies were deposited in their present positions during the early Tertiary. Distribution of uranium and vanadium ore deposits may have been effected during disruption of ground-water conditions related to structural deformation and igneous intrusions in early Tertiary time. The possibility that the ores were derived from hypogene solutions related to early Tertiary igneous activity is suggested by the zonal distribution of some important groups of deposits with respect to laccolithic mountains and by the presence of pitchblende in some of the ores. These and other seemingly conflicting data and theories must be further evaluated and integrated before the problem of the source and time of deposition of the Colorado Plateau ores can be resolved.

The possible relationships between uranium and vanadium ore deposits on the Colorado Plateau and the volcanic material that in part makes up the host rocks were investigated during 1951. Field studies and microscopic examination of the ores indicate a relationship between the ore minerals and montmorillonite clay: the vanadium hydromica formerly called roscoelite is believed to be derived from montmorillonite. During devitrification of volcanic ash, ground waters may have leached alkalies, uranium, vanadium, and other substances from the ash.

Depth profiles in areas on the Colorado Plateau indicate that resistivity depth measurements may be helpful in planning and directing exploratory and development drilling in areas where the base of the ore-bearing sandstone lies at depths of 200 feet or less. The measurements will serve to delineate sedimentary structures in the upper part of the Salt Wash sandstone member of the Morrison formation. They will depict areas underlain by sequences of thick mudstone and thin sandstone beds as well as areas underlain by thick sandstone or by sequences consisting of more sandstone than mudstone. Not all the factors controlling favorable conditions in the sandstone are reflected by resistivity measurements, but in general the measurements seem to classify the ground fairly accurately. As the method is limited to exploring for favorable zones at less than 200 feet in depth, it may, therefore, have only a limited use in the exploration of the Morrison formation because of the scarcity of untested ground above this depth. This method may, however, be applicable in searching for favorable zones in the Shinarump conglomerate.

The results of a few natural potential measurements made along traverses that cross mineralized ground in the Spud Patch area indicate that this method may be helpful in locating favorable parts of the ore-bearing sandstone.

A suite of polished sections of material containing uraninite and sulfides

*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.

f[illegible] deposits on the Colorado Plateau is being studied. Bornite and chalcopyrite, [illegible]oth, accompany uraninite almost invariably in these specimens. In material [illegible] the Gray Dawn mine, San Juan County, Utah, the paragenetic sequence indi[illegible]d is chalcopyrite (earliest), uraninite, and chalcocite. Exsolution types of [illegible]ture have been noted of chalcocite in uraninite and of chalcopyrite in bornite.

Phosphates

Northwest phosphate.--Studies of the mineralogy of suites of rock from the w[illegible]h phosphate zones in widely separated localities in Wyoming, Idaho, and Montana are in progress. Work to date shows that in all the rocks studied the phosphate mineral is carbonate-fluorapatite, as it is in Florida. Of the clay minerals, hydromica is found in samples from all localities, and kaolinite and montmorillonite are found in several of the samples.

Southeast phosphate.--The material in the land-pebble phosphate deposits of Florida appears to reflect the character of the underlying Hawthorn formation of Miocene age. In the northern part of the district, where the deposits are underlain by limestone of the Hawthorn, the phosphate-bearing beds contain abundant phosphatized limestone fragments. In the southern part, where the deposits are underlain by sandy and silty rocks of the Hawthorn, the phosphate-bearing beds contain little or no phosphatized limestone.

Recent studies have shown a positive correlation of the topography of the surface of the Hawthorn formation underlying the land-pebble district with the present surface topography of the district. There also appears to be a relationship between the topography of the surface of the Hawthorn formation and the size of the phosphate particles; in general, fine phosphate particles are found on Hawthorn "lows" and coarser particles on Hawthorn "highs."

Studies of the sorting and size of material in the surface sands overlying the phosphate deposits in the land-pebble district have shown that the degree of sorting and the coarseness increase from west to east. The data indicate that the better-sorted and coarser sand is found on topographic highs, and that the more poorly sorted and finer sands are located on lows. As indicated by the studies, the sorting and size of the material in the phosphate deposits differ greatly from those of the surface sands.

Samples from past drilling on one property in the Florida deposits contain up to 0.25 percent uranium. The material is not obviously different in physical properties or mineral composition from the normally less uraniferous phosphorite, nor is it an example of leached-zone rock.

Phosphate studies in the eastern Gulf of Mexico.--Results of the survey of the bottom sediments off the west coast of Florida show that material containing small amounts of phosphate is found in five areas-- two areas are in the Gulf of Mexico; the other areas are in Tampa Bay and in the lower courses of the Myakka and Peace Rivers. The phosphate in at least four of these areas appears to have been derived from the peninsular phosphate deposits.

Analytical methods

Spectrography.--The so-called single-grain method of spectrographic identification has been applied to the following types of materials: mineral grains, X-ray powder spindles, fragments of mineralized wood, chemical precipitates, insoluble residues, and various thin coatings and corrosion products. To date the

wave lengths and sensitivities of the analytical line used in this method have been checked for 46 of the 69 elements for which standard plates have been prepared on the basis of 1 mg of sample.

The scope of the semiquantitative spectrographic method for the analysis of minerals and rocks has been increased from 55 to 68 elements that can be estimated in one exposure of a 10 mg sample.

X-ray diffraction studies.--A preliminary examination has been made of the feasibility of using the Norelco spectrometer for low-angle X-ray diffraction studies. No definite conclusions have been drawn, but, in the event that it is not possible to use the instrument for that purpose, a camera will be specifically designed and constructed for low-angle studies.

Radiometry.--A method for determining the natural radioactivity of samples has been developed that will differentiate several members of the thorium-uranium radioactive series and will account for loss of equilibrium in most cases.

Chemistry.--The investigation of a variety of organic compounds as possible reagents for the determination of thorium is hampered by the unavailability of many promising reagents and by the excessive cost of others. Of 11 new organic compounds tested during the quarter, one was especially sensitive, enabling the detection of less than 0.01 microgram of ThO_2 per ml of solution.

Geochemistry and petrology

Radon and helium in natural gas.--In the investigation of the distribution and origin of radon and helium in the Panhandle gas field, Texas, permeability profiles show numerous combinations of porous zones or even separate thin porous zones that retain their identity from well to well for several miles. Thus there is the possibility that the permeability profiles, by systematic matching, may yield clues as to sedimentary and structural conditions and may provide a background for the interpretation of radon measurements.

Various attempts have been made to solve the nonlinear differential equation for flow of compressible gas through porous media, as a means of interpreting the observed radon content of the natural gas in terms of spatial distribution of radon and its parent radioelements in the gas reservoir. These attempts have been without success, and this approach has been abandoned. In a new attempt to obtain a qualitative working relationship of transient gas flow phenomena, the flow equation for compressible gas through porous media was modified so that is is now linear.

Radioactive solid hydrocarbon grains have been found in the anhydrite-dolomite zone ("A" zone) of the Panhandle Big Lime in five wells. This presence of highly radioactive hydrocarbons is the first tangible evidence for the existence of possible source material for the radon in the Panhandle field.

Leaching tests.--Leaching tests on uranium minerals were continued on the coarse-grained granite of Rubideaux Mountain, Riverside County, Calif. The leaching was done with 0.2 N, 1.0 N., 2.5 N, and 5 N HCl and HNO_3 and with 2.5 N acetic acid. The 0.2 N HCl removed only 25 percent of the uranium; the other acid solutions removed 50 to 60 percent of the uranium.

Isotope geology.--The results of nine isotope analyses to test the uniformity

of a single crystal of galena from the Tri-State mining district near Joplin, Mo., are being evaluated. These analyses show that the relative abundance of the radiogenic isotopes increases progressively outward from the nucleus of the crystal. The outermost layer in the progression contains 2 or 3 percent more radiogenic isotopes than the nucleus. The increment includes uranogenic lead and thorogenic lead in about the same proportions as they are formed in the earth's crust by radioactive decay of uranium and thorium. The gray oxidized film, such as ordinarily coats the outer surfaces of galena crystals, was found to be different in isotopic composition from any sample from the interior of the crystal, although approximately intermediate in content of radiogenic isotopes.

Front Range pitchblende deposits.--The thesis is presented that pitchblende deposits of the Colorado Front Range mineral belt are related to zoning of metalliferous deposits, that a number of Front Range and other mining districts display such zoning, and that the zonal pattern may be a valuable clue in prospecting for new uranium deposits. Known pitchblende deposits appear to be associated with chalcopyrite in the transition zone between the area of pyrite-gold veins and the area of silver-lead veins. Zoning in a given district, however, is commonly modified by local conditions. For pitchblende deposits in the Colorado Front Range, at least six qualifying factors might require consideration: bostonite dikes, mineral associations, paragenetic sequence, scale and complexity of zoning, vertical zoning and depth of mineralization, and fault pattern.

It is concluded from a study of the differential leaching of uranium, radium, and lead from pitchblende that a relative enrichment in both radium and lead results from leaching of uranium from oxidized pitchblende in H_2SO_4 solutions. The results of the study have a direct application to the problems of geologic age determinations based on lead-uranium ratios and to the problem of the re-evaluation of radioactive sulfide-bearing material in mines and dumps.

Mineralogy and petrology

Analytical work was done on pure samples of the following uranium minerals; studtite, billietite, ianthinite, renardite, diderichite, orange schoepite, curite, and a green uraninite.

In the investigation of metamict minerals, "high-temperature fergusonite" has been synthesized from a dry melt and is apparently identical with heated (about 850°C) metamict fergusonite. The equimolecular proportions of Y_2O_3 and Nb_2O_5 were not actually melted, but the temperature was high enough to promote sintering in the mechanically mixed and compressed pellet. Even though melting did not take place, there was complete chemical reaction to form the yttrium niobate from the constituent oxides.

It has been observed in the course of the studies of metamict minerals that many of the recrystallized metamict minerals show minor differences in their d-spacings from specimen to specimen that probably reflect differences in chemical composition. This condition has been observed in the huttonite pattern (resulting from the ignition of metamict thorite) and in the euxenite patterns and is likely to appear in many of the other metamict minerals.

TRACE ELEMENTS RESEARCH QUARTERLY PROGRESS REPORT

January 1 to March 31, 1952

SANDSTONE-TYPE DEPOSITS

Colorado Plateau geologic studies

Stratigraphic studies
by L. C. Craig

Morrison formation

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 November 26, 1951.

Compilation of data and preparation of reports and maps were continued throughout the period of this report. This work is preliminary to the preparation of a final report on the Morrison study. Specifically, the compilation of data on the lithofacies and sedimentary petrography studies was essentially completed and rough draft reports on the work were prepared; data compilation on the regional stratigraphic, sedimentary structure, and pebble studies was continued. The preliminary report, TEI-180, was edited and slightly revised for publication as a chapter in a Geological Survey bulletin. A paper entitled "The Morrison formation of the Colorado Plateau region" was presented by L. C. Craig in Washington, D. C., at a meeting of the Geological Society of Washington on March 26, 1952.

Data compilation of all the phases of stratigraphic studies should be essentially completed during the next quarter, April 1 through June 30, and additional rough-draft material for the final report will be prepared.

Triassic formations (pre-Morrison formations)

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

Field work on the Triassic formations was begun in the past field season but was limited to three months' work. Compilation of the collected data has been partially completed. During this report period the sedimentary petrography laboratory has analyzed most of the samples of Triassic rocks collected during the past field season. Other work on the Triassic was recessed during this quarter to further the work on the final report of the Morrison formation.

Field work during the 1952 field season will be directed almost entirely to study of the Triassic formations of south-central and eastern Utah. This field work will begin in Kane County, Utah, during the next quarter.

Ground-water studies
by L. C. Craig

Ground-water studies were begun in 1950 to determine both the present and past ground-water conditions in the ore-bearing rocks of the Morrison formation, and the influence that these waters may have had on the genesis and localization of the ore deposits.

The ground-water studies were recessed in September 1951 to permit evaluation of the results. The report on this work has been revised and is being reviewed. The report summarizes the available evidence regarding present

ground-water conditions, including composition of the waters and the permeability and porosity relations in the ore-bearing sandstone, and discusses the geologic features that would have influenced ground-water conditions in the past. It is suggested that the more favorable time for the accumulation and concentration of ore-bearing ground-water solutions was during the period after deposition of the Salt Wash and before regional deformation in early Tertiary time.

The report will be transmitted in the next few months. Active ground-water studies will be resumed in the latter part of June 1952. This work will be aimed primarily at determining the horizontal and vertical transmissibility relations of all the exposed sedimentary formations on the Colorado Plateau in order to test the capacity of the rocks to transmit ore-bearing solutions to the sites of known deposits.

Mineralogic studies
by Alice Weeks and Leonard Riley

In the mineralogic and petrologic studies of the Colorado Plateau deposits, work was done during the quarter on the so-called "blue-black" ores of the Bitter Creek and Whitney mines in Montrose County, Colo. and from two deep drill holes (600 - 700 feet) in Long Park and Atkinson Mesa, Colo. These ores show little or no visible carnotite but they contain up to several percent uranium. Eleanor Thompson is working on the material from the Bitter Creek and Whitney mines and has prepared enough montroseite (black vanadium mineral) from material from the Whitney mine for chemical analysis. This is the third mine in which this new vanadium mineral has been found. In the Whitney material the montroseite seems to be more closely associated with uranium than in the material from the Bitter Creek and Matchless mines (the other two mines in which montroseite has been found). It is important to establish whether

these "blue-black" ores represent a pre-carnotite stage of mineralization and to determine the mode of occurrence of the uranium in them. It is hoped that the present studies will accomplish this purpose.

A suite of specimens from the drill holes mentioned above is being studied. The distribution of the radioactivity in the material is being investigated by J. H. Rosholt and L. F. Rader, Jr. in the Trace Elements Section Denver Laboratory. The radioactivity disequilibrium noted in these samples is probably due in part to continued emanation after grinding and in part to radium migration and subsequent deposition. Stripping-film covered thin sections are being made of this material in the Washington Laboratory and are being studied by Riley as an aid in determing the distribution of radioactivity.

Work by Alice Weeks on rauvite is described in a report "New occurrences of rauvite from the Colorado Plateau" which was being edited at the end of the quarter. The abstract follows:

"Five new occurrences of rauvite from the Colorado Plateau have been studied. Rauvite is a calcium uranyl vanadate named in 1925 by Frank L. Hess and described only from the original locality at Temple Mountain, Emery County, Utah. New data include specific gravity of 2.91, revised chemical formula of $CaO.2UO_3.5V_2O_5.16\ H_2O$, X-ray spacings, indices of refraction, and biaxial negative character. Rauvite is thought to be a recent alteration product of tyuyamunite."

The five new localities for rauvite are Monument No. 2 mine, Apache County, Ariz.; Arrowhead mine, Mesa County, Colo.; Small Spot mine, Mesa County, Colo.; Cactus Rat mine, Thompson, Utah; and Jack Claim, Utah, 10 miles west of Gateway, Colo.

Late in December 1951 and early in January 1952 about 50 samples of mudstone and siltstone samples received from R. A. Cadigan and A. C. Waters of the Survey were run on the X-ray spectrometer to determine what clay minerals the rocks contain and, in particular, whether montmorillonite is present in the samples that react to the benzidine test. For some samples the identification

of constituent minerals from the spectrometer pattern is satisfactory and rapid. In the patterns of some other samples, however, little or no montmorillonite can be identified although the samples give a positive reaction with benzidine. These are chiefly samples containing quartz, feldspar, and kaolinite which have many strong lines in the X-ray pattern. It may be that the benzidine test is more sensitive for small amounts of montmorillonite than is the X-ray spectrometer. In order to test this, Eleanor Thompson has prepared standard samples of quartz and clay minerals in various proportions to be run on the X-ray spectrometer. This is time consuming but important because at present there is little basis for estimating even the relative abundance of the constituents of mudstone from the X-ray patterns. It is recognized that the precision of the quantitative results is limited because of the problem of orientation of the platy clay minerals.

At the end of the quarter a report on alteration of mudstone and one on the stratigraphic set of clays (mentioned in previous quarterly reports) were in preparation and should be completed in the next quarter. A summary of the clay studies was presented by Alice Weeks at the conference on the Plateau deposits in Grand Junction, January 6, 1952.

In the investigations of minor elements in the Colorado Plateau by Leonard Riley in cooperation with E. M. Shoemaker (see TEI-218, pp. 14-15) the selection of a relatively complete set of mill pulps has been started. Pulps from at least 800 different mines have been collected and the preliminary work of classifying them has started. A report on the results of the study of minor elements was presented by Riley and Shoemaker at the Grand Junction conference mentioned above and again at a similar conference held by AEC people in Grand Junction, January 11 and 12, 1952.

A suite of polished sections of material containing uraninite and sulfides

is being studies by Riley. The presence of bornite and/or chalcopyrite accompanying uranite is nearly universal in these specimens. In material from the Gray Dawn mine, San Juan County, Utah, the paragenetic sequence indicated is chalcopyrite (earliest), uraninite, chalcocite. Exsolution types of textures have been noted of chalcocite in uraninite and chalcopyrite in bornite. These studies will continue in the next quarter.

Geophysical prospecting
by W. E. Davis

The objective of the geophysical exploration project is to evaluate the use of various geophysical methods as possible guides in the exploration for carnotite ores on the Colorado Plateau. All effort has been placed on the carnotite ores in the Salt Wash member of the Morrison formation; only cursory consideration has been given thus far to ores in other formations. Resistivity methods have been emphasized as preliminary tests for favorable ground. The known range of applicability of other geophysical methods, such as natural potential, magnetic, and geothermal methods, suggests little, if any, correlation with ore occurrences or with structures favorable for ore.

Accomplishments and results

Between April 26 and December 14, 1951, electrical-resistivity surveys, using both horizontal- and depth-profiling methods, were made prior to drilling in areas on Blue and Outlaw Mesas, Mesa County; Spud Patch, San Miguel County; Atkinson Mesa and Long Park, Montrose County, Colo. Natural-potential measurements were also made in the Spud Patch and Long Park areas.

During the quarter, as the results of drilling became available, these surveys were evaluated in terms of reliability and applicability. A report giving complete details will be submitted in the near future.

The results of shallow and deep horizontal profiling measurements indicate that this method will not give reliable results. Gray, hard, calcareous sandstone lenses overlying the ore-bearing sandstone cause large variable surface resistivities. Measurements of large magnitude are usually observed over areas where high-resistant material lies near the surface. Such near surface conditions will be reflected as resistivity "highs", which mask anomalies caused by changes at depth in profiles of measurements made to a given depth as in horizontal profiling.

The results of depth profiling indicate that resistivity depth measurements will be helpful in planning and directing exploratory and development drilling in areas where the base of the ore-bearing sandstone lies at depths of 200 feet or less. The measurements will serve to delineate sedimentary structures in the upper part of the Salt Wash member of the Morrison formation. They will depict areas underlain by sections consisting of thick mudstone and thin sandstone and parts of the sandstone that contain more interstitial mudstone. The measurements also will serve to locate areas underlain by thicker sandstone or where more sandstone than mudstone is present at depth. All of the factors controlling favorable conditions in the sandstone are not reflected by resistivity measurements but, in general the measurements seem to classify the ground fairly accurately. The chief drawback to the application of these methods to the search for ore in the Morrison formation is the

scarity of untested ground in which the ore-bearing zone lies at depths less than 200 feet. Possibly these methods will have wider application in the search for ore in the Shinarump formation. More tests are needed, however, to establish its effectiveness there and to show whether or not a combination of depth-profiling and diamond-drilling is cheaper and more effective than diamond-drilling alone.

In areas where the Salt Wash sandstone lies at depths between 300 and 400 feet and between 500 and 700 feet, the results of depth profiling are not very encouraging. The resistivity-depth curves do not show prominent discontinuities with changes in sub-surface conditions at positions corresponding to the ore-bearing sandstone. High conductivities in materials lying near the surface tend to mask small anomalies associated with changes at depth. The use of higher currents in making resistivity measurements in these areas may magnify small anomalies at depth and thereby provide a means of mapping subsurface changes at greater depths.

The results of a few natural potential measurements made along traverses crossing mineralized ground in the Spud Patch area indicate that this method may be helpful in locating more favorable parts of the ore-bearing sandstone. This method may be especially helpful in areas where the sandstone lies near the surface. In these areas resistivity-depth measurements may not be reliable because changes in moisture conditions in the upper part of the sandstone cause anomalies that are not related to changes in subsurface geological conditions.

An aeromagnetic survey of 3,000 square miles in the Uravan Mineral Belt was completed during March with the objectives of determining the basement rock configuration and any magnetic anomalies that might reflect concealed intrusives or structures possibly related to the occurrence of ore on a broad regional basis. In general, preliminary evaluation of the survey suggests little magnetic variation in a deep-seated basement rock and no apparent anomalies of significance. The compilation of the survey data as a magnetic contour map together with full evaluation will require at least 6 months.

Future plans

In the coming quarter and during the summer field season, additional and modified techniques will be tried on an experimental basis. Specifically, resistivity measurements will be tried using a $7\frac{1}{2}$ KVA power source in the hope that changes in lithologies at greater depth--on the order of 600 feet--may be indicated with greater certainty. Detailed gravimeter surveys will be made over several known ore bodies to determine if measurable gravity contrasts exist over the ore-bearing channels. Experimental seismic surveys will also be made, although it is apparent that no consistent results will be obtained because of lateral variations in lithology of the beds overlying the ore-bearing sandstone. As suggested by the few natural potential measurements in the Spud Patch area, this method will be further applied in known areas to determine its applicability and limitations.

Relation of uranium to volcanic materials in Triassic and Jurassic formations

by A. C. Waters and H. C. Granger

The possible relationships between uranium and vanadium ore deposits on the Colorado Plateau and the volcanic material which, in part, makes up the host rocks were investigated in 1951. Structural deformation and igneous intrusion in early Tertiary time suggest that distribution of uranium and vanadium ore deposits may have been effected during ensuing disruption of ground-water conditions.

Volcanic debris, now altered to clay minerals, has been recognized in the Salt Wash and Brushy Basin members of the Morrison formation and in the Shinarump conglomerate and Chinle formation. Field studies and microscopic examination of the ores indicate a relationship between the ore minerals and montmorillonite clay; the vanadium hydromica formerly called "roscoelite" is believed to be derived from montmorillonite.

A paragenetic sequence of events, shown by examination of thin sections, begins with secondary enlargement of quartz grains, possibly related to devitrification of glassy volcanic material. This is followed by solution of quartz grains and formation of vanadium hydromica, possibly related to a change in ground-water conditions.

During devitrification of volcanic ash, ground waters may have leached alkalis, uranium, vanadium, and other substances from the ash. The absence of blanket deposits of uranium and vanadium minerals implies either 1) reactivated circulation of metal-bearing ground water, or 2) introduction of metal-bearing juvenile waters into the ground water system. Additional problems must be investigated before final conclusions can be drawn.

VEINS, IGNEOUS ROCKS, AND RELATED DEPOSITS

Relation of uranium to post-Cretaceous volcanism

The investigation of the relation of uranium to post-Cretaceous volcanism, begun early in the summer of 1951, led to the discovery of volcanic materials in the pre-Cretaceous formations containing, and associated with, the carnotite-bearing ores on the Colorado Plateau. Work was therefore concentrated on this relationship as reported in a preceding section and investigation of the relation of uranium to post-Cretaceous igneous activity was postponed. It is hoped that this investigation can be resumed during the first quarter of fiscal 1953.

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

Preliminary studies have been made on the relation of pitchblende deposits to the zonal distribution of metalliferous deposits in the Colorado Front Range.

In several districts of the Front Range, particularly the Central City district, the known pitchblende deposits appear to be associated with chalcopyrite in the transition border zone between the area of pyritic-gold veins, toward the center, and the area of silver-lead veins, on the peripheries. The following quotation taken from the summary of a talk presented by Leonard at a meeting of the Pick and Hammer Club in Denver on February 29, 1952, will serve to convey other tentative results of these preliminary studies.

"This memorandum presents the thesis that pitchblende deposits of the Front Range mineral belt are related to zoning of metalliferous deposits, that a number of Front Range and other mining districts display such zoning, and

that the zonal pattern may be a valuable clue in prospecting for new uranium deposits. The concept of the relation of pitchblende to zoning is developed with one goal in mind: to stimulate and guide the systematic search for pitchblende deposits. That search is for deposits of pitchblende, not for specimens. Doubtless minor occurrences of pitchblende will be present in several zones, just as the common base-metal sulfides are distributed through several zones even when their major concentration is in one or two. If the ideas developed are valid, knowledge of zoning should point us toward the major concentrations of pitchblende."

An ". . . accompanying map . . . delimits for 10 districts in the Front Range mineral belt the areas that appear most favorable for the occurrence of pitchblende deposits. Boundaries of the favorable areas are, in many places, indeterminate; therefore the map should serve to guide prospecting, not to police it.

"The districts shown . . . are by no means the only ones in which the concept of zoning seems applicable to the search for pitchblende. Preliminary work on 7 other Front Range districts indicates that zoning may be a suitable guide to pitchblende in most of these districts.

"Mineralization broadly similar to that found in the Front Range mineral belt is widespread in many mining districts of the Western States; ore deposits in some of these districts show analogous patterns of zoning. So far as the writer knows, none of the classic examples of zoning (such as Butte and Tintic) has been systematically searched for pitchblende. Other districts show zonal patterns that are less distinct, or less well known to geologists. Pitchblende (or highly anomalous radioactivity) occurs in at least five representatives of this type: Leadville, Aspen, Ouray area, Cripple Creek, and Coeur d'Alene.

"The concept of zoning is merely a first approximation of knowledge about the distribution of any group of ore deposits. However, the very breadth of the concept has made it especially useful in prospecting for new ore bodies. Zoning in a given district is commonly modified by local conditions. With regard to pitchblende deposits in the Front Range, at least six qualifying factors must be borne in mind: bostonites, mineral associations, paragenetic sequence, scale and complexity of zoning, vertical zoning and depth of mineralization, and fault patterns. Some of these factors are of general import. However, we may expect local geologic factors to play important roles in individual districts. Until we can recognize and evaluate the local factors, we are forced to rely on generalized knowledge.

"This initial application of the concept of zoning to the search for pitchblende is presented in preliminary form only. It is not a completed study. Rather, it is a partial compilation of the work of many other people. While it may raise more problems than it solves, it clearly points the direction for new--and we hope productive--work.

"Pitchblende deposits have been found in places far removed from known metalliferous districts showing zoning. Optimists will expect to find more. The fact that zoning, where applicable, offers a guide for systematic search for certain pitchblende deposits means only that we have not yet recognized comparable guides to the 'odd-ball' occurrences."

Colorado Front Range mineralogic, geochemical, and petrologic studies
by George Phair

In the work on the mineralogy and petrography of the radioactive bostonite dikes and associated pitchblende-bearing veins near Central City, Colorado, most of the quarter was spent in preparing a report on the work to date. This report, "Radioactive Tertiary porphyries near Central City, Colorado, and their bearing on pitchblende deposition," by George Phair, should be ready for distribution during the next quarter. An advance summary of the report was given by Phair at a meeting of the Geological Society of Washington April 23, 1952.

The first draft of a summary report, "Notes on the differential leaching of uranium, radium, and lead from pitchblende in H_2SO_4 solution" by George Phair and Harry Levine, is being edited. This report summarizes field work at the Wood and Kirk mine dumps on Quartz Hill near Central City, Colo., and laboratory work on material collected from the dumps. Conclusions drawn are that a relative enrichment in both radium and lead results from leaching of uranium from oxidized pitchblende in H_2SO_4 solutions and that the amount of enrichment is approximately proportional to the amount of uranium leached. The results have a direct application to the problems of geologic age determinations based on lead-uranium ratios and to the problem of the re-evaluation of radioactive

sulfide-bearing material in mines and dumps.

Work will be resumed in the coming quarter on geologic age determinations on hard pitchblende hand-picked from high-grade ore samples from the Copper King mine, Larimer County, Colo., and on uraninite crystals separated from a pre-Cambrian (?) granite from the Central City district. As pointed out in TEI-218 (p. 12), these age studies will be of great significance in determining the paragenesis of the Colorado Front Range deposits and are being undertaken in cooperation with Lorin Stieff and Tom Stern of the isotope geology project.

Kiyoko Shimamoto's work on the radioactive cerite deposit near Jamestown, Colorado, will be described in a report "Notes on the occurrence of britholite in the radioactive cerite deposit near Jamestown, Colorado," to be prepared during the next quarter (see TEI-218, p. 12).

During the quarter Mrs. Shimamoto made a laboratory study of material from the highly radioactive Chalk Mountain rhyolite near Climax, Colo., at the request of Charles Pierson of the Survey's Mineral Deposits Branch. Conclusions are that most of the radioactivity is concentrated in beta-uranophane but some uranitite is also present. The laboratory study involved heavy-liquid and magnetic separations, hand picking of grains under the microscope, alpha-plate studies of dispersed grains and X-ray identifications, together with analytical work.

GEOCHEMISTRY AND PETROLOGY OF LIGNITE

by J. M. Schopf and Maurice Deul

Geochemical, mineralogic, and petrologic investigations of lignites continued during the quarter. The purpose of the investigations is to determine the mode of occurrence of uranium in lignites, to determine the mineral and chemical composition of specific deposits, and to study the geochemistry, mineralogy, and petrology of uraniferous lignites to establish the origin of the contained uranium.

During the quarter a method for extracting tannin from lignites was being investigated at the Trace Elements Washington Laboratory. The standard methods of tannin analysis are being studied with eleven samples of representative tannin extracts obtained from researchers at the National Bureau of Standards. These methods are not direct but they can probably be modified to work for tannin extractable from lignite. Lignites are known to contain tannin; tannin is known to form uranium complexes and it seems fruitful to investigate the possibility of uranium occurring in lignite associated with tannin. The problem is to extract tannin from the various complex organic materials that constitute lignite. Tannins have the property of precipitating uranium and other elements like molybdenum and vanadium from acid solutions and hence the extraction and determination of tannin should be useful in determining the relationship of uranium to other trace elements in the lignites and the relationship of the amount of uranium to the stratigraphic position of any single layer. It is important to make such a study and similar studies because to know that the uranium is associated with the organic material is not enough ; it must be determined which of the organic constituents are most closely associated with the uranium.

It is also planned to investigate the different resins in the lignite as having possibly acted as ion-exchange resins in fixing uranium.

Radiometric studies were made in more than usual detail on the core from one deep hole drilled on Slim Buttes. This work was done at the Coal Geology Laboratory in Columbus, Ohio, where a small reserve of coal from all the drill holes is kept. This study has yielded a pattern of radioactivity which is consistent with a stratified deposit involving normal sedimentary depositional control. The upper portion of the coal bed and the clay immediately overlying it contain the greatest concentration of radioactive elements; a lower portion of the coal bed contains the lowest concentration. Neither the extreme top nor the extreme bottom layers of coal show extremes of radioactivity. Nevertheless, the upper layers of coal are the most radioactive, but associated clay, of relative purity as judged by microscopic monitoring of samples, also showed a fairly high level of radioactivity. Less radioactive clay from beneath the coal bed did not show a positive correlation between organic matter and radioactivity. Review of several hypotheses to explain sedimentary uranium concentrations in the light of this information seems to favor a theory of diagenetic emplacement. Although this appears plausible and fairly adequate except for knowledge of a specific source of uranium, no conclusions are justified on the basis of one core.

Most of the quarter was spent by Deul in compiling material for the summary informational report as mentioned in previous quarterly reports (see TEI-218, p. 18). This report, "Summary of cooperative investigations of uraniferous lignites: I," by Maurice Deul, is now completed and should be ready for distribution during the next quarter.

PHOSPHATES

Northwest phosphate
by R. W. Swanson

Areal geologic mapping

Aspen Range-Dry Ridge area, Caribou County, Idaho

An area of some 450 square miles in southeastern Idaho that contains many of the richest and most accessible phosphate deposits is being mapped at a scale of 1:12,000. About one-third of this area has been mapped to date and two 7½-minute quadrangles are being prepared for release.

Field work for the geologic map of the Johnson Creek quadrangle was done by a number of geologists, but R. A. Gulbrandsen has been given the responsibility for compilation of map and report for release. The map was more than three-quarters compiled by the end of the quarter. The area is much broken by faulting, no pattern of which can be applied as yet to problems of phosphate mining. When more of the surrounding area is mapped, however, we should have a better foundation for such interpretations.

The geologic map of the Dry Valley quadrangle is being compiled by E. R. Cressman, though several geologists have contributed to the mapping. The map was compiled by the end of the quarter. The cross sections and report were likewise essentially complete. It is planned to submit this report in May for open file release.

Soda Springs quadrangle, Caribou County, Idaho

The map and report by F. C. Armstrong covering about two thirds of the Soda Springs 15-minute quadrangle were nearly ready to submit for open file release and processing last summer, but owing to other activities, the work had to be recessed. No work was done on this map or report during this quarter.

Lyon quadrangle, Montana-Idaho

Nearly three-fourths of the Lyon 30-minute quadrangle (Beaverhead and Madison Counties, Mont., and Clark and Fremont Counties, Idaho) has been mapped by G. C. Kennedy at a scale of 1:24,000. Maps of the area have been compiled and were submitted during March for editing and preparation for release. Much of the work on the two reports to accompany these maps for open file release is also finished and it is hoped that these reports and maps can be submitted for open-file release in the near future.

Centennial Range phosphate area, Montana-Idaho

An area in the Centennial Range, mostly within the SE 1/4 Lyon quadrangle (Beaverhead County, Mont., and Clark and Fremont Counties, Idaho), that contains rich deposits of phosphate has been mapped at a scale of 1:12,000 by F. S. Honkala. It is hoped that the map and a report can be submitted for open-file release during June or July. The final map and report cannot be submitted before next fall or winter.

NW 1/4 Willis quadrangle, Beaverhead County, Montana

The NW1/4 of the Willis 30-minute quadrangle has been mapped by W. B. Myers. The map and the open file report are in preparation, and should be forwarded during May for open-file release. Topographic base maps of the area are not yet available.

SW1/4 Willis quadrangle, Beaverhead County, Montana

The SW1/4 Willis 30-minute quadrangle has been mapped by W. R. Lowell. The map is compiled and a report for open file release is in preparation.

Stratigraphic studies

The stratigraphic and analytic information assembled as a part of the sampling program is being prepared for release, first on open file and later in Survey Circulars and TEI reports. Data for the sixth Circular were submitted in February for open-file release and will be submitted for Circular editing and processing in the near future. Data for the next set of three Circulars, covering samples collected in 1949 and 1950, are being prepared. Each Circular of unclassified data will have a companion TEI report containing the same information plus classified data. Four such Circulars are now being processed in Washington prior to printing and two more are nearly ready for submission. Others should follow in fairly rapid succession.

Each Circular of abstract stratigraphic and analytic information will be followed by a companion Circular of columnar sections and a TEI report with classified information added. Assembly and compilation of the data for these columnar sections are in progress.

Correlation studies of the stratigraphy in the area centering about Jackson Hole, Wyo., are in progress by R. P. Sheldon.

Other studies

Other project efforts are devoted to geochemical studies by K. B. Krauskopf, who plans to complete current studies before the middle of June; and ownership classification of all western phosphate lands by E. C. Willey and T. M. Cheney. Progress has been slow on this classification problem, but it is hoped that the first data will be ready for release in the near future.

The work indicated above will continue during the fourth quarter of fiscal year 1952. Field work for the coming summer will start about the middle of May. The first efforts will be devoted to a limited sampling program in Lincoln County, Wyo., which should be completed by the end of June, weather permitting.

Southeast phosphate

Geologic studies
by J. B. Cathcart

Geologic work in the land-pebble phosphate district during the quarter ending March 31, 1952, included studies of (1) the origin and distribution of the phosphate and uranium; (2) the grain-size distribution in the surface sands; (3) the relation of the topography of the Hawthorn formation to the phosphate particle size of the deposits and to the topography of the northern part of the district; (4) the relation of uranium and phosphate; (5) stratigraphic studies; and (6) mine mapping and sampling.

Detailed information on these studies follows:

Distribution and origin of phosphate, by J. B. Cathcart and D. F. Davidson

Progress on studies of the origin of the phosphate deposits during the quarter were presented in a report at the AIME-SEG meeting in New York in February 1952. This report is in preparation as a TEI report. The authors' abstract follows:

"The land-pebble phosphate district of Florida is a part of the Gulf Coastal Plain. The geologic formations cropping out in the district are the Miocene Hawthorn, Pliocene Bone Valley, and Pleistocene terrace sands.

"The Bone Valley formation consists of a lower strongly phosphatic unit and an upper less phosphatic unit. This paper is concerned principally with the lower unit, which contains the bulk of the minable phosphate deposits of the district.

"The land-pebble district is divided into two parts: a northern part in which the P_2O_5 content of the phosphate is high and a southern part in which it is generally lower. The material in the phosphate deposits in these areas appears to reflect the character of the underlying Hawthorn formation. The northern part of the district is underlain by limestone of the Hawthorn formation, and the phosphate deposits contain abundant phosphatized limestone fragments. The southern part is underlain by sandy and silty Hawthorn, and the phosphate deposits contain little if any phosphatized limestone.

"The northern part of the district may be divided into two areas; the phosphate deposits of the central area containing large phosphatic particles with low P_2O_5 content and the deposits of the outlying area containing smaller phosphatic particles with a higher P_2O_5 content.

"Recent studies have lead to the conclusion that the pebble phosphate of the central area of the northern part of the district is depositional and that the phosphate in the outlying belts may be, at least partly, residual in origin."

The origin of the phosphate will continue to be an important part of the geologic studies and as more drilling information, particularly in outlying areas, is obtained the relationship outlined above will be refined, or altered.

Distribution and origin of uranium, by J. B. Cathcart

All assay data on uranium in the phosphate products were synthesized as of February 1952, and maps of distribution of the uranium in the phosphate products were completed. The report is in progress. The highest uranium grades are in the -14 mesh (pebble) fraction, and in the lower-grade pebble phosphate deposits. In addition, preliminary studies indicate that these low phosphate pebble deposits occur on tops or flanks of ridges on the buried Hawthorn surface.

Work on the distribution and origin of uranium in the leached zone has barely been started. Mineralogical work and detailed sampling by Z. S. Altschuler and others indicate the uranium is secondarily enriched in the leached zone. Indications at present are that the Peace River valley contains the most continuous leached zone and possibly the highest-grade uranium in the district.

A great many gamma-ray logs are available and will continue to be made on current company drill holes. As these are compiled, our knowledge of the distribution of the leached zone will be much advanced, and until these data are compiled, the relationships between the leached zone and the pre-Pleistocene topography, the present streams, and the Hawthorn topography will be unknown. Work in the future will attempt to define these relationships, as well as stratigraphic relationships and grade distribtuion.

Relation of uranium and P_2O_5 in the phosphate deposits of Florida, by J. B. Cathcart

In February 1952, TEM-315 entitled, "Correlation between uranium and P_2O_5 in a coarse pebble phosphate deposit, Florida", by K. B. Ketner, was transmitted to the AEC. The author's abstract follows:

"Phosphate nodules from each of 18 prospect holes in a coarse pebble phosphate deposit were separated according to size and vertical position within the minable zone. Results of analyses for P_2O_5 and uranium are plotted on scatter diagrams and coefficients of correlation are given. Correlation tends to be positive among nodules of uniform size and negative among nodules of diverse size. Uranium content of individual samples cannot be derived from known P_2O_5 grade alone."

During the quarter ending March 31, 1952, additional work was started on several other deposits. Further statistical work is planned for the future as a part of several economic reports on prospecting in the French-Noralyn area, Polk Co.; the Plant City area, Hillsborough County; and the Pinecrest area, Hillsborough County.

Relation of the "topography" of the Hawthorn formation to size of phosphate particles in the deposits, and to present topography in the northern part of the land-pebble district, by D. F. Davidson

The author's abstract of a TEM report in preparation follows:

"Recent studies have shown that there is a positive correlation of 'topography' of the surface of the Hawthorn formation, which in general underlies the phosphate deposits of the land-pebble district, and topography in the district. In addition there is a relationship between the 'topography' of the surface of the Hawthorn formation and phosphate particle size in the deposits, in general, fine phosphate particles are found in Hawthorn 'lows' and coarser phosphate is found on Hawthorn 'highs'."

Future work will consist of refining the general relationship stated, as detailed information on the Hawthorn "topography" is compiled.

Grain size distribution in surface sands, by D. F. Davidson

The work described above showed that present-day topography in the district parallels the topography of the surface of the Hawthorn formation. Work on grain size distribution in surface sands was undertaken in the hope that the relation

of size distribution in the surface sands would aid in understanding the reasons for the parallelism. The preliminary study has been completed. The author's abstract from the TEM report in preparation follows:

"A study of the sorting and the size of material in the surface sands of the land-pebble phosphate district shows that both the sorting and the size change across the district. The degree of sorting and the coarseness of the material increase from west to east. Comparison of grain size and sorting data and topography indicates that better sorted and coarser material is found on relative topographic highs and that finer and more poorly sorted material is found on relative lows.

"Study of size distribution of materials in 9 pits in the economic phosphate deposits of the district shows that the sorting and size of the material of the deposits are greatly different from those of the surface sands."

Future work will expand the study as started by Davidson, and in addition, studies will be made of present beaches and off-shore bars, to see if there is any relationship, and to see if a relationship exists between grain size and sorting, and the terrace sands of the Pleistocene.

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

The objectives of studies of stratigraphy in the land-pebble district are to determine the age, and relations of the Bone Valley formation to other Pliocene formations, to the underlying Miocene Hawthorn formation, and to the overlying Pleistocene sands. In addition, relations within the Bone Valley formation and within the Hawthorn formation are being studied.

Past work indicates that the Bone Valley, Caloosahatchee, and Alachua formations are contemporaneous, or nearly so, but that the Citronelle formation may overlie the Bone Valley formation, and may be Pleistocene in age. Future work on these relations must be done largely by drilling.

The Hawthorn formation, middle Miocene in age is phosphatic and is very likely the source for most of the economic phosphate deposits in Florida. Field reconnaissance studies in northern Florida, Georgia, and South Carolina in March 1952 showed that the Hawthorn formation contains phosphate in these areas. As

part of this reconnaissance. 22 holes were drilled with a jeep-mounted auger. Three holes in northern Florida, one in Georgia, and three in South Carolina penetrated Hawthorn rocks containing phosphate nodules. Further work will be done to determine the stratigraphy of the Hawthorn, particularly the position within the Hawthorn of the phosphatic zones. The first of such studies will be on deep-well cuttings stored by the Florida Geological Survey at Tallahassee. Work on comparative stratigraphy will be recessed until October.

The problem of the contacts of the Bone Valley formation with the underlying Hawthorn formation and the overlying Pleistocene sands, and the relations of these formations is being studied in the open pits in the district. Plane-table maps of mines are being made as time allows. The Homeland mine, Polk County, was mapped in March, and further cuts at the mine will be mapped as they are exposed. Well exposed sections at the Sydney mine, Hillsborough County, and the Pauway mine, Polk County, will be mapped in the near future, and when other sections are exposed at these mines they will be mapped in order to obtain three-dimensional relationships.

Stratigraphic studies were begun of sections exposed by mining in the phosphate district. The objectives of this work are to make chemical, mineralogical, mechanical, and statistical analyses of mine-face samples from several of the active mines in the district. One complete channel sample will be taken at each of the mines for each lithologic stratum from the Hawthorn formation to the surface. Each sample will be disaggregated and washed to separate the -150 mesh fraction. The remaining sample will be screened for mechanical analysis, and any fraction containing phosphate particles will be floated to separate the phosphate. Each fraction will be given a heavy-liquid separation and the heavy minerals determined. A complete chemical analysis will also be made of all fractions.

Future work on mine samples will depend upon results obtained from the first sample. At least a year will be needed to complete all the work on all the samples. A final report on a correlation of all the work will be written when studies are completed.

Mineralogy and petrology
by Z. S. Altschuler

Northwest phosphate studies

In the continuing investigation of the mineralogy and petrology of the northwest phosphates, studies are in progress of the mineralogy of suites of rock from the rich phosphate zone in widely separated localities. This work is being done by James P. Owens. New samples represent the upper phosphate zone in the Idaho section at Leefe, Wyoming, the lower phosphate zone of the Idaho section at Fort Hall, Idaho, and the "B" bed of the Wyoming Section at Gros Ventre Slide, Wyoming. In addition, samples also represent the "D" bed in the trench at the West Fork of Blacktail Canyon, Montana, and from the upper phosphate zone of the "B" bed at Hot Springs, Idaho.

These rocks are being studied optically, chemically, and by X-ray diffraction. Highlights of the work to date show that in all the rocks studied the phosphate mineral is carbonate-fluorapatite. Of the clay minerals, hyromica is present in samples from all localities; at Fort Hall it was the only clay mineral found; at Leefe it was the most abundant, kaolinite and montmorillonite being found in successively lesser quantities; at Gros Ventre and Blacktail Canyon kaolinite was found in addition to hydromica.

Of the heavy and accessory minerals identified, barite is present in significantly high trace quantities (<1%) at both Leefe and Gros Ventre and sphalerite is present in unusually high trace quantities (<1%) at Blacktail Canyon in a

sample from the same zone in which pyrite occurs.

In continuing this work it is hoped, in addition to identifying the major and minor constituents of the rocks, to establish the level of uranium content of the non-phosphatic constituents.

Southeast phosphate studies

Samples from past drilling exploration conducted by J. B. Cathcart of the Geological Survey on one property in the Florida phosphate deposits contain up to 0.25 percent uranium. The samples are not obviously different in physical properties or mineral composition from the normally less uraniferous phosphorite, nor are they examples of leached zone rock.

Crushed pulp samples (the only material available) of this material were studied under the microscope and were fractionated by heavy-liquid and magnetic separation. A large fraction of each sample was unusually magnetic, responding even to a hand magnet. This fraction consists of normal sedimentary apatite with minute inclusions of magnetite. Hitherto, it has been said in the literature that magnetite is not present in the Bone Valley formation. No satisfactory concentration of the uranium could be effected by magnetic methods; the same amount of uranium is present in all of the fractions.

Fresh unground material has been requested from Cathcart. He has found in samples from redrilling in the same area that the equivalent percent uranium is equal to or higher than that of the original samples. It is hoped that significant results can be obtained from a study of these later samples.

A study was in progress at the end of the quarter of a suite of drill samples collected from a well at Plant City by Robert Stewart of the Survey. This well is significant in two respects; it is situated roughly at the edge of the economic deposits and it extends into limestone of the Hawthorn formation. The samples, as a group, are quartzose and calcareous marls with some pure quartz sands corresponding to the "overburden", and phosphatic marls corresponding to the "matrix". The work is being done by Robert Berman. The material was treated in the laboratory by disaggregating by soaking in water, separating by repeated decantations into clastic and non-clastic fractions, and further breaking down of the clastic fraction by heavy-liquid separation. This resulted in three fractions, (1) clay and carbonate rich, (2) quartz rich, and (3) apatite rich. These were chemically analyzed with the X-ray spectrometer and charts were made.

Results of this work to date are as follows: In the topmost 18 feet the rock is a friable quartz sand cemented by 10 percent of clay and containing 10 percent of carbonates as cement and shell fragments; apatite, zircon, and magnetite are present in trace amounts (<1%). From 18 feet down to 60 feet the rock is phosphatic and quartzose marl. The apatite content increases rapidly to a maximum of 20 percent; at 48 feet it decreases and at 60 feet it is only about 2 percent of the rock. The carbonate from 18 to 60 feet is principally dolomite and the clay in this zone is principally montmorillonite with minor amounts of attapulgite at the base. Somewhere between 60 and 83 feet (all samples have not yet been studied) there occurs a change equivalent to that between the Bone Valley and the Hawthorn formations. Thus, in two samples representing the intervals 83-95 feet and 112-115 feet the rock is highly quartzose limestone with only trace amounts of apatite nodules.

This drill-sample suite will be described in greater detail when the work

is completed.

General studies

In the investigation of the carbonate-apatite problem, X-ray studies of pure end members representing fluorapatite and hydroxlapatite, and of carbonate-fluorapatite were continued during the quarter. X-ray spectrometer patterns were obtained on a scale large enough to insure a precision of 0.001 A for the end members and of 0.002 A for the carbonate-fluorapatite by comparison with silicon standards; with the use of internal quartz standardization the same order of precision was also obtained. The results, shown below, offer definite proof that carbonate-fluorapatite is structurally different from hydroxyl- or fluorapatite.

Unit Cell Constants

Compound	a_o	c_o	c_o/a_o
$Ca_{10}(PO_4)_6(OH)_2$	9.413 A	6.872 A	0.730 A
$Ca_{10}(PO_4)_{6-x}(CO_3)_yF_{2+z}$	9.386	6.878	0.733
$Ca_{10}(PO_4)_{6-x}(CO_3)$	9.344	6.881	0.736
$FeCO_3$	4.71	15.43	
$MgCO_3$	4.73	15.51	

The significant change in the unit cell is in the a_o dimension. The magnitude of the change in cell constants can be assessed by reference to the cell constants of the end members of the iron carbonate-magnesium carbonate series as shown in the table.

It should be stressed that the above changes have been tested by mixing, by repetition of measurements on different materials of the same composition, and by identification from film patterns. It should be emphasized that the apatite common to the Bone Valley formation of Florida and the Phosphoria formation of

the northwest, as well as Moroccan and other marine phosphorites, is carbonate-fluorapatite.

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

Interest in the phosphate content of the bottom sediments in the eastern Gulf of Mexico was stimulated in 1948 by the discovery of phosphatic sediments in a small area off St. Petersburg, Fla. by Stewart. Notations of bottom type, recorded on charts of the U. S. Coast and Geodedic Survey, suggested that sediments of similar character covered the inner 25 miles of the continental shelf between Tarpon Springs and Fort Myers, Fla. Profuse dinoflagellate blooms (red tide), which are thought to be spawned by phosphate-rich waters, develop periodically in this same general area. This correspondence in distribution suggested that the red tide and the phosphate in the bottom sediments might have a common origin, and that the phosphate might be in the process of formation at the present time. On the other hand, it seemed possible that the phosphate on the sea floor might be a submarine extension (or reworked submarine extension) of Miocene and Pliocene phosphate deposits on the Florida peninsula, or that the phosphate may have been contributed by rivers draining the peninsular deposits. The deposits were deemed worthy of investigation because they might cast light on the origin, distribution, and habits of phosphate deposits elsewhere, particularly on the Florida peninsula.

Accordingly, a combined oceanographic and geologic study of the Gulf of Mexico off the west coast of Florida was begun by the Geological Survey in July 1951 to determine the areal distribution, quality, and particularly the source and manner of deposition of phosphate. Studies to date have been confined chiefly to continental shelf between Tarpon Springs and Fort Myers, Fla., and to the

lower courses of rivers entering the Gulf in this area. Reconnaissance studies of more limited scale have also been made as far west as Mobile, Ala.

In these studies a total of 1500 bottom samples, 15 dredge hauls, and 9 cores have been collected from approximately 2000 nautical miles of traverse.

The distribution of samples by area is given in the following summary:

	Area	No. of samples
1.	Continental shelf between Mobile, Ala. and Tarpon Springs, Fla.	180
2.	Continental shelf between Tarpon Springs and Fort Myers, Fla.	833
3.	Deep ocean floor--eastern Gulf of Mexico.	9 (cores)
4.	Tampa Bay.	188
5.	Charlotte Harbor and Pine Island Sound.	157
6.	Lower courses of the Caloosahatchee, Myakka, Manatee, Little Manatee, Alafia, and Hillsborough Rivers.	142

In addition, this project has received 38 bottom samples and 10 sea water samples collected by the U. S. Fish and Wildlife Service vessel, "Alaska", from widely separated areas of the Gulf of Mexico.

The results of these studies to date show that sediments with an appreciable phosphate content are confined to the following areas:

1. Near-shore area between Venice and Englewood, Fla., in a belt about 5 miles wide and approximately 20 miles long.

2. Area between St. Petersburg and Tarpon Springs along the 10-fathom contour--approximate dimensions are not yet available.

3. Southeastern part of Tampa Bay in a belt about 3 miles wide and 5 miles long.

4. Lower 10 miles of the Myakka River.

5. Lower 15 miles of the Peace River.

The P_2O_5 contents of individual samples from these areas range from about 0.30 percent to 13.4 percent, and the uranium contents range from 0.0001 percent to 0.0040 percent. The Venice-Englewood area is considerably higher in phosphate than any of the other areas.

With the possible exception of the St. Petersburg-Tarpon Springs area, the

phosphate in these regions appears to have been derived from the peninsular phosphate deposits. The phosphate in the Venice-Englewood area is traceable to the shore where it is exposed in beach sands and in a phosphatic sand and gravel bed about 2 feet thick. Similarly, the detrital phosphate particles along the lower course of the Myakka River appear to have been derived from this same bed. Phosphate in the lower reaches of the Peace River has undoubtedly been derived from the peninsular deposits. Likewise, the phosphate in Tampa Bay appears to have been eroded from the Florida phosphate fields and carried into Tampa Bay by the Alafia and possibly the Little Manatee Rivers.

Other areas of the Gulf of Mexico from which samples are available are uniformly low in phosphate and uranium. In fact, they are no higher in phosphate uranium than marine sediments generally. The maximum phosphate and uranium contents as determined from the analyses of about 100 samples from other areas of the Gulf are 0.21 percent and 0.0005 percent respectively.

Plans for the coming quarter include:

1. Additional sampling and dredging on the continental shelf between the Cocohatchee and Anclote Rivers to fill gaps in previous lines and to obtain more dredge hauls.

2. Collection of about 100 sea water samples from the shelf area between Tarpon Springs and Fort Myers.

3. Collection of about 400 samples in the Venice-Englewood phosphate area and a comparable number of samples from the phosphate area between St. Petersburg and Tarpon Springs.

4. Collection of approximately 100 beach samples between Fort Myers Beach and Tarpon Springs.

5. Collection of about 50 bottom samples and a comparable number of water samples from the upper courses of the Peace, Myakka, Little Manatee, and Alafia Rivers.

6. Collection of about 400 samples in areas not previously sampled between Galveston, Texas, and Key West, Fla. Samples will be obtained on one of the scheduled cruises of the "Alaska".

7. Reconnaissance sampling for phosphatic sediments on the narrow shelf of the Florida Straits.

ANALYTICAL METHODS

Spectrography
by Claude Waring

Following the preparation by Jules Stich of standard plates for 69 elements for use with the Gaertner prism spectrograph in the so-called single-grain method (see TEI-218, p. 33), work continued during the quarter on a compilation of the wave-lengths and sensitivities of the analytical lines used in this method. The standards mentioned above have been prepared on the basis of 1 mg of sample. The method is particularly useful for the spectrographic analysis of small mineral grains and X-ray powder mounts. To date the wave lengths and sensitivities of 46 of the 69 elements have been checked. The method has been applied to the following types of materials: mineral grains, X-ray powder spindles, fragments of mineralized wood, chemical precipitates, insoluble residues, and various thin coatings and corrosion products. Samples submitted have ranged from 0.1 to 1.0 mg. A report on the method, "Spectrographic identification of mineral grains", by Jules Stich, is in preparation. During the next quarter work on the sensitivities will continue and the possibility of adapting the method for use with the Hilger prism spectrograph will be investigated.

Work continued during the quarter on improvements to and modifications of the semiquantitative method. Progress was made on the application of the Leeds and Northrup microphotometer to automatic scanning of the plates. Plates are now examined by eye and this results in considerable eye strain to the analyst. The automatic scanning is being designed to eliminate this eye strain and to lessen the chances of error. Time studies have also indicated that automatic scanning will save time in reading the plates. Tracings of the standard plates are being recorded and scales are being prepared to aid in identifying the

analysis lines in the tracings.

The increase in the coverage of the semiquantitative method from 55 to 69 elements (see TEI-182, p. 25) is described in "A semiquantitative spectrographic method for the analysis of minerals, rocks, and ores (II)", by C. L. Waring and C. A. Annell (TEI-215, February 1952). The abstract follows:

"The scope of the semiquantitative spectrographic method for the analysis of minerals, rocks, and ores previously described as determining 55 elements, has now been increased to 68 elements which can be estimated in one exposure of a 10-mg sample. Flucrine, the 69th element, requires a separate exposure for some materials. The method has been used to complete about 185,000 determinations in the past two years. Listed in this report are 336 chemical check analyses that indicate approximately 8 percent disagreements in the magnitude of one 10 percent bracket. No chemical and spectrographic results differ by a factor of more than 10."

In the studies by Claude Waring and Helen Worthing of the determination of lead in trace amounts a few discrepancies between chemical and spectrographic results were investigated. Results of tests showed that:

1. 10% Pb in a U_3O_8 matrix showed a depressing effect on the Pb lines 2873, 2833, 2823, and 2802A. No effect was observed on Pb lines 2663, 2614, 2446, 2443, and 2394A.

2. 1% Pb in a U_3O_8 matrix showed no effect on Pb lines except line 2833A which was slightly enhanced. There is possibly some interference with this line by uranium.

3. 0.1% Pb in a U_3O_8 matrix showed only Pb lines 2833, 2802, and 2614A lines as detectable. There was interference by uranium with line 2833A and the other lines were very slightly enhanced.

4. A 4 a concentration of 0.01% Pb in a U_3O_8 matrix, no Pb lines were detected.

Matrix effects on Pb lines will continue to be studied during the next quarter.

A report on the results of an investigation to determine if germanium volatilizes during ashing of lignites at 800°C was prepared during the quarter and is now being edited (see TEI-218, p. 34).

Work on the determination of thorium in samples high in uranium (Claude Waring, Charles Annell, Helen Worthing); the determination of impurities in uranium as a means of analyzing complex refractory oxides (Annell and Worthing); and the detection of trace amounts of thorium without prior chemical concentration (Waring, Annell, Worthing), has been recessed indefinitely because of more pressing work.

Investigations in the Denver laboratory of contamination of samples during grinding (see TEI-218, p. 35; TEI-182, pp. 27-28) was recessed during the quarter, owing to press of analytical work.

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.

Radiometry
by Frank Senftle

Investigations of the thoron method for the analysis of small amounts of thorium is in progress by Ray Champion. The thoron line has been assembled and trial runs have been made. A considerable amount of sputtering occurred during the runs due to uneven heating of the crucible. This has been overcome to some extent by changing the shape of the crucible and its position in the induction coil. Further trouble has been found in the electronic circuit, owing to interference from the induction furnace. This will be investigated during the next quarter.

An alpha spectrograph is being constructed by Ray Champion and Jim Bracken to determine whether satisfactory U and Th analyses can be made on samples with very low activity. The amplifier has been completed and initial tests indicate satisfactory operation. Checks on the camera focus have been made and the focus is satisfactory. Film fogging due to cathode glow has been partly corrected by installation of filters. It is planned to use a slightly different cathode-ray tube to further reduce this effect.

A test run has been made with the instrument and the peak heights and densities have been measured on the densitometer. These initial results indicate that enough resolution may be possible to distinguish thorium and uranium quantitatively.

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. One mc each of Ce^{144}, Cs^{137}, and Tl^{204} have been obtained from the Oak Ridge National Laboratory for trace studies. In addition, 5 mc of Ra D have been obtained from the Eldorado Refinery at Port Hope, Ontario. Tests were started during the quarter to determine the amount of activated charcoal needed to produce saturation adsorption of bismuth in a bismuth-lead solution of a given concentration.

Work on the development of a rapid radiochemical method for the determination of U and Th in monazite (Francis Flanagan, Jesse Warr, F. S. Grimaldi) has been recessed indefinitely because of the press of other work.

A report was in preparation during the quarter by John W. Rosholt in the Section's Denver Laboratory on a method of determining the natural radioactivity of samples. This method will differentiate several members of the thorium-uranium radioactive series and will account for loss of equilibrium in most

cases. Procedures for determining thorium, radon, radium, and radium D are substantially satisfactory. Further work on this method will be an investigation of the possibility of determining Th^{230}, in non-Th^{232} bearing ores.

Data are still being compiled by Flanagan on the comparison between radiometric and chemical uranium determinations made in both the Denver and Washington laboratories on a variety of materials. When these comparisons are statistically analyzed the results will be reported.

A program was started during the quarter to check periodically from a health standpoint on the radioactivity in the Washington Laboratory. A preliminary survey showed that one room where high-grade samples are stored had radioactivity slightly above the tolerance level. Five 55-gallon drums with hand-locked rubber gaskets have been obtained for storage of these samples. Seven ionization-chamber pocket dosimeters have been issued to personnel most likely to receive radiation. These dosimeters are being read and recharged every week and accumulated doseage is being recorded.

Chemistry
by F. S. Grimaldi

Fluorimetry

Work in fluorimetry was continued by Mary Fletcher in the Washington Laboratory, consisting of making minor modifications to existing instruments to make them more compact, stable, and versatile. The sensitivity of fluorimeters now in use is more than adequate for all analytical purposes and no attempts are being made to increase sensitivity.

Methods of uranium and thorium analysis

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

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

During the quarter 11 new organic compounds obtained from the research collection of General Aniline and Film Corporation were tested. Nine of these dyes gave good color reactions with thorium. One was especially sensitive, enabling the detection of less than 0.01 microgram of ThO_2 per ml of solution. Preliminary tests were made on an additional 10 reagents but none were sensitive enough to warrant further study.

Fine Organics, Inc., of New York has been contacted about the possibilities of synthesizing 11 other organic reagents that contain structural groups that chelate with thorium. In addition, Professor Charles White of the University of Maryland has arranged for the synthesis of several organic reagents by some of his graduate students.

Work will continue during the next quarter on the investigation of promising reagents. The work is hampered by the unavailability of many promising reagents and by the excessive cost of others.

Methods of analysis for aluminum and phosphorus

The molybdenum blue method for the determination of micro-amounts of P_2O_5 in the presence of As, Si, and Ge by Harry Levine and F. S. Grimaldi

The literature search on the above analytical method was completed during the quarter. No general method for the determination of small amounts of P_2O_5 in the presence of Si, As, and Ge has been reported. Laboratory studies have begun 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 for performing 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.

Methods of analysis for miscellaneous elements and compounds

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

In the geologic age studies being undertaken under the isotope geology project of the program of fundamental research in the geochemistry of uranium, it is apparent that basic information is needed about isotopic distribution in lead from sea water and in lead from marine deposits of different geologic ages.

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, ion-exchange studies on the concentration of heavy metals in sea water were pursued. Representative samples of ion exchange resin and of the acid eluant from typical column operations were prepared for spectrographic analysis. Resin samples were ignited to constant weight at 600°C. Acid eluant fractions were evaporated and dried at 300°C. These were submitted for spectrographic analysis.

Standard solutions were prepared of a radioactive isotope of lead for use in ion exchange and chromatographic studies of the concentration of lead.

As lead from sea water is concentrated in marine sediments, typical samples of marine sediments are being collected for the separation of lead. Samples of a manganese nodule from the Pacific and of rock salt from Michigan were prepared for spectrographic analysis.

GEOCHEMISTRY AND PETROLOGY

Distribution of uranium in igneous complexes

E. S. Larsen, Jr.

Work progressed during the quarter on fundamental research in the distribution of uranium in igneous complexes. The project is now fully staffed. Much of the work on the project to date has been in organization such as acquainting the new members of the project with the techniques involved and with the purpose of the research.

Leaching studies were continued by Frank Cuttitta of the Chemistry Unit on the coarse-grained granite of Rubideaux Mountain, Riverside County, Calif. The leaching has been done with 0.2 N, 1.0 N, 2.5 N, and 5N HCl and HNO_3 and with 2.5 N acetic acid. The 0.2 N HCl removed only 25 percent of the uranium present, the other acid solutions removed from 50 to 60 percent of the uranium present. The minerals separated from this rock are being tested to determine the total amount of uranium and the amount soluble in acid in each mineral.

Several pairs of granite samples are being tested to determine the relation between weathering of the granite and the amount of soluble uranium. These samples are:

a) A sample of the altered surface rock and one of the freshest rock obtainable at the bottom of the granite quarry at Conway, New Hampshire.

b) A sample of friable granite (grus) and the hard "fresh" rock from a large residual boulder embedded in the grus, from southern California. Chemical analyses show little difference in composition between the two samples.

c) Samples of grus and fresh rock from the Green Valley quartz-diorite of southern California.

d) Samples similar to those of (b) from the Idaho batholith.

Six chemical analyses of granitic rocks from the Idaho batholith have been completed and there have been many uranium determinations made on special rock samples. A suite of about 25 samples of lavas and tuffs from the great volcanic mass of the San Juan Mountains, Colorado, carefully selected to represent the rock types as well as the formations has been submitted to the chemists for uranium determinations for the purpose of comparing volcanic rocks with granitic rocks.

Minerals have been separated from several granitic rocks from the Idaho batholith, the California batholith, from New Hampshire, and from the volcanic rocks of the San Juan Mountains of Colorado.

Rare elements in the rocks and minerals of the southern California batholith are being determined spectrographically and nearly half of the necessary determinations have been made.

Some of the work of the project is seriously handicapped by lack of an adequate method for the determination of trace amounts of thorium (a few parts per million or less). Much time is being spent in the laboratory in testing chemical, spectrographic, and radiometric methods and it is hoped that the problem will be solved.

It is planned to do field work during the next quarter in the southern California batholith to collect some needed special samples.

Synthesis of uranium-bearing minerals
by Earl Ingerson

Sol and Jeanne Silverman had made a start in synthesizing uranium-bearing apatite and apatite-like minerals. When they left, this work had to be discontinued until replacements could be found.

Synthesis Programs - the following minerals have been synthesized to provide material for standards and to familiarize Jansen with the types of products obtained by synthesis and the methods of checking these products available in this laboratory.

Mineral	Method of	X-ray check	Electron microscope exam.	Remarks
Autunite	Beintema 1/ (1938)	Autunite (?) poss with extra H_2O		
Uranocircite	"	Either uranocircite or autunite	Homogenous product	
Zippeite	Dana (1951)	Zippeite	Homogenous product	
Bassetite	Beintema (1938)			
Parsonsite	"	Not parsonite Pattern unknown		
Torbernite	"	Torbernite		Finely crystalline, Apparently homogenous in optical mike.
Uranospinite	Dana (1951)	Pattern checked by Frondel "in proper group - may be fully hydrated form"		
Parsonite (Rerun)	Beintema (1938)	Not exact pattern for parsonite		Penfield H_2O deter. in process.

1/ Beintema, 1938 - On the composition and the crystallography of autunite and meta-autunite. Rec. Trav. Chim.- Pays - Bas. 57, 155-75 (1938) Min. Abs. 7, 237 (1938-40).

On February 28, 1952, George J. Jansen entered on duty and has made a start on the project in another direction. He has gone through much of the literature on uranium minerals and has abstracted all of the articles, or parts of articles, dealing with methods of synthesis. An almost completed bibliography of uranium minerals by George Switzer has aided Jansen considerably in his search for such methods.

Jansen has also spent about 3 weeks in the X-ray and electron microscope laboratories learning techniques of identification of fine-grained phases from powder patterns and electron micrographs. These will be essential methods of identifying cryptocrystalline products of many of the experiments.

The attached summary indicates the uranium minerals thus far prepared by Jansen, and the methods used in their synthesis.

Irving Friedman reported for duty on May 1, 1952, and has been placed in immediate charge of the project on crystal synthesis. He is ordering additional equipment and his group will be ready to make much more rapid strides in the near future.

X-ray diffraction studies
by Charles Christ

The first phase of the project involving X-ray diffraction studies of radioactive and associated minerals and including a study of X-ray mineral identification methods, namely the acquisition of personnel and equipment (see TEI-218, p. 27) has been virtually completed. Howard T. Evans and Mrs. Gabrielle H. Donnay have entered on duty during the quarter. Some further advances have been made in the acquisition of basic equipment. It can now be expected that the project will now move rapidly into its second phase, that of

solving some of the scientific problems involved.

Some beginnings have been made on these problems. A preliminary examination has been made of the feasibility of using the Norelco spectrometer for low-angle studies. No definite conclusions have been drawn but in the event that it is not possible to use this instrument for that purpose the design and construction of a camera specifically designed for low-angle studies will be carried out. Low-angle X-ray studies will probably be important in several problems, including the study of carbonate apatite and metamict minerals.

Howard Evans has made a preliminary investigation of the IBM equipment in the Geological Survey with the view of making arrangements for having certain complex crystal-structure computations made with this equipment. Further discussions will be held with the persons in charge of this work. Evans has also begun discussions with Howard Jaffe of the Survey on the probably new rare-earth carbonate mineral being studied by Jaffe with the view of working out the X-ray crystallography of this mineral and determining its relationship to other known carbonates. Evans has also begun preliminary reading and discussions on the general apatite problem. He and the writer have begun active work on the design and construction of the Selsyn motor analog computer.

Mrs. Donnay has undertaken an analysis of the general problem of the identification of minerals by the X-ray diffraction powder method. As was indicated in the original purpose of this project the writer thinks that in general more thought needs to be put into the overall problem of increasing the speed and accuracy of analyzing mixtures by X-ray methods. The work of Mrs. Donnay is a preliminary step in this direction. She has submitted a

draft of a report on the subject based on her previous work in this field and containing recommendations as to what can and should be done on the problem.

Work will continue during the next quarter along the lines indicated.

Isotope geology

Radioactive elements and their decay products

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

At the beginning of the quarter the authors attended a Geological Survey conference on problems connected with the origin of the Colorado Plateau deposits at Grand Junction, Colorado, January 5-7, 1952. A detailed description was given of the problems involved and the results obtained from the study of the lead-uranium ages of the Colorado Plateau uranium ores.

On returning from Grand Junction the authors visited H. C. Urey of the Institute of Nuclear Studies, University of Chicago, and J. J. Katz of the Argonne National Laboratory. Discussions were held with Professor Urey on possible extension to uranium of the O^{16}/O^{18} temperature studies that Katz is undertaking (on samples prepared by the authors) and the success that might be expected (see TEI-218, p. 24). Urey did not think that the results could be predicted on purely theoretical grounds. He is interested in the problem, however, and will be glad to cooperate on it.

Samples provided to Katz consist of several purified samples of uraninite and carnotite. Katz at the time of the visit was in the process of assembling the fluorination apparatus used in the quantitative extraction of oxygen from the uranium minerals.

The paper "A preliminary determination of the age of some Colorado Plateau uranium ores by the lead-uranium and lead-lead method," by L. R. Stieff and T. B. Stern was presented at the joint sessions of the AIME and the Society of Economic Geologists in New York on February 19, 1952. The abstract of this report was given in TEI-218, pp. 24-25. The condensed version of the paper as given in New York has been expanded into a fuller report that is now being edited.

Four galena samples and 15 samples of uranium ore were prepared for age determination studies during the quarter. Chemical and isotopic analyses have been received for approximately 30 samples in addition to those reported on at the New York meeting. Preliminary calculations on these samples were being made at the end of the quarter and will continue during the next quarter.

Isotope geology of lead by R. S. Cannon

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 of the origin and occurrence of metallic ores, to improving exploration methods for the discovery of ores, and to solving many broader problems of geology and cosmogony. Immediate efforts are being directed toward several fundamental problems: empirical studies of geologic variations as guides to proper sampling; evaluation of laboratory methods and measurements in isotopic analysis of lead; isotopic composition of primeval lead; and isotopic composition of lead in sea water.

All mineralogic and chemical investigations so far have been made in laboratories of the Geological Survey, where the project was initiated, but the lead isotope analyses have been made in the mass assay laboratory at Y-12, Oak Ridge.

A mass spectrometer is now being built in a Survey laboratory for isotope analysis of lead. In addition, arrangements have been made during the quarter with Professor Harrison Brown to carry on some of these investigations through joint effort. On completion of the new geochemical laboratories at California Institute of Technology, various geologic materials are to be investigated by radiometric and isotope dilution methods of analysis. The isotope dilution method will make it possible to survey the isotopic composition of the traces of lead in igneous rocks. During the quarter a start was made on several geologic phases of this cooperative undertaking: geologic evaluation of problems and sample materials, preparation of purified concentrates of typical rock-forming minerals for reagent use in the laboratory, and consultation on laboratory methods for mineral separations with specialists in the Denver, Washington, Florida, and New York areas.

In the Washington laboratory, work was continued during the quarter on evaluating isotope variations in lead ores in order to establish valid sampling procedures. Samples of commercial galena concentrates from 5 lead-ore concentrating mills in two western mining regions were prepared for isotope analysis. These samples will yield part of the data needed for testing the uniformity of isotope ratios throughout single lead-ore mines or deposits, and throughout mining regions.

Nine isotope analyses to test the uniformity of a single crystal of galena from the Tri-State mining district near Joplin, Missouri, have been completed and the results are now being evaluated. These analyses present a picture of large variations in isotope ratios that are fairly systematic. From the original nucleus of the crystal outward the abundance of the radiogenic isotopes increases progressively. The outermost layer in this progression contains two or three percent more of radiogenic isotopes than the nucleus. The increment

includes uranogenic lead and thorogenic lead in about the same proportions as they are formed in the earth's crust by radioactive decay of uranium and thorium. The gray, oxidized film, such as ordinarily coats the outer surfaces of galena crystals, was scraped from one face of this crystal, analysed, and found to be different in isotopic composition from any sample from the interior of the crystal, although approximately intermediate in content of radiogenic isotopes. This result is an informative discovery of one of the unsuspected hazards that can be expected to beset the selection of galena samples for isotope analysis and the interpretation of reported variations.

These data also have important implications as to theories of ore genesis and the age of the earth as calculated from lead isotope data. The full significance of this information can not be evaluated until it is supplemented by analogous information on materials from other known geologic environments. A number of samples have been chosen and collected for this purpose, and these are being prepared for isotope analysis as time permits.

Plans for next quarter include, in addition to preparation of additional samples for lead isotope analysis, further study and interpretation of data already obtained, study of lead and lead/uranium relationships in marine materials, and perfection of the program of cooperative investigations with Brown and colleagues.

Radon and helium investigations
by G. B. Gott, H. Faul, and G. E. Manger

Objectives

The broad objective of the radon and helium investigation is to determine the distribution and origin of radon and helium and their parent radioactive elements in the Panhandle gas field, principally in Moore and Potter Counties,

Texas. The anomalous concentration of radon and helium in the natural gas suggests that an abnormal concentration of uranium and its decay products must be contributing gaseous decay products into the gas reservoir, although no radioactive source materials of sufficient concentration are known.

During the quarter, the shorter-term objectives were (1) to determine, with reference to producing gas wells, the stratigraphic and structural position of the dolomite or other reservoir rocks containing significant concentrations of radon, (2) to relate the radon content of the natural gas to radium or uranium compounds giving rise to the radon, and (3) to investigate anomalies in the distribution of helium as an indication of possible present-day local sources of influx of helium into the Panhandle gas field.

Accomplishments and results

A base map showing nearly all wells sampled for radon, as well as roads, buildings, drainage, and section lines where physically marked by fence rows, etc., is nearing completion. The map is being compiled from existing maps and aerial photographs on a scale of 4,000 feet equal 1 inch, but will be reduced, probably to 2 miles equal 1 inch.

Compilation of the radon measurements for 350 producing gas wells made during the summer of 1951 is complete. These data will be shown on the base map together with contours of equal radon content.

Gamma-ray profiles showing stratigraphic variation in radioactivity and possible zones of radon influx have been compiled from the few available gamma-ray logs of wells in the Panhandle field. These profiles will be compared with stratigraphic and structural interpretations of the various operating companies in order to clarify the relations between the lithologies, natural gas producing zones, and the radon content of the natural gas.

Abundant pitot-tube and other gas-flow data pertaining to the producing porous zones exposed in various wells have been collected from the various gas companies operating in the Panhandle field in order to construct permeability profiles. Some data of poorer quality and representing wider-spaced vertical intervals have been collectible only by tedious search of the original drilling records. Other data have been derived from nearly complete systematic sampling at closely spaced vertical intervals throughout the entire producing zone. Considerable time has been necessary to reduce the data to a form suitable for the construction of the permeability profiles, and this has been particularly true of the poorer quality data, which are the more numerous. Results to date demonstrate that the permeability profiles show numerous combinations of porous zones or even thin separate porous intervals that retain their identity from well to well for distances of several miles. Thus, there is the possibility that the permeability profiles may yield, by systematic matching, clues as to sedimentary and structural conditions as well as provide background for the interpretation of radon measurements. It is expected that an initial application of these permeability data to the areal distribution of radon measurements will be made within a month or two.

Various attempts have been made to solve the non-linear differential equation for flow of compressible gas through porous media as a means of interpreting the observed radon content of the natural gas in terms of spatial distribution of radon and its parent radioelements in the gas reservoir. These efforts have been without success, and this approach has been abandoned. In a new attempt to obtain a qualitative working relationship of transient gas flow phenomena, the flow equation for compressible gas through porous media was modified so that it becomes linear. The radon transport equation is now in the process of being solved by use of the time-dependent pressure and velocity re-

lationships developed in this manner. It is anticipated that this equation when solved will permit a better interpretation of radon measurements in terms of the spatial distribution of radon within the gas reservoir volume and indirectly will lead to an approximation of the source distribution giving rise to the radon.

Study of well cuttings from radon-bearing gas wells in the Panhandle gas field continues. As previously reported, radioactive solid hydrocarbon grains have been found in the anhydrite-dolomite zone ("A" zone) of the "Panhandle Big Lime" in 5 different wells. A spectrographic analysis of one sample of the hydrocarbon indicated that it contained 0.3 percent uranium. Individual samples have not been analyzed chemically because of the small size of the samples. Radiometric analyses of the hydrocarbon grains indicated that the samples contain up to 0.7 percent equivalent uranium. The presence of highly radioactive hydrocarbons is the first tangible evidence that has been obtained for the existence of possible source material for the radon.

Arrangements with several petroleum and natural-gas companies have been made to obtain additional well cuttings for further search for uranium- and radium-bearing materials.

Dolomite core material has been obtained from several wells adjacent to our area of interest. This dolomite rock constitutes the principal gas reservoir which to date has been the main source of radon. These pieces of dolomite are being thoroughly examined by chemical analysis, nuclear track stripping film, radon measurements, and radiometric counting (1) to isolate and identify the chemical compounds of uranium and radium that are the sources of the radon, (2) to determine whether uranium or radium is present in the pore spaces of the

dolomite, or is distributed in the matrix, as within the dolomite grains, or along the grain boundaries, or otherwise, and (3) to determine possible equilibrium or lack of equilibrium between uranium and radium. Other material has been analyzed by a U. S. Bureau of Mines laboratory and is now being investigated at the Oak Ridge National Laboratory to determine possible direct or inverse correlation between radon emanation and porosity and permeability of the porous medium. All the preceding is aimed at increasing the usefulness of the radon transport equation by reducing the number of assumptions attendant upon its use and at obtaining a better understanding of the geology of the radon source materials. As our core samples were rather recently acquired, not enough time has been available to complete any of these investigations and derive conclusions therefrom.

As a preliminary step in the investigation of the apparent anomaly of greater down-dip concentration of lighter helium gas in heavier hydrocarbon gas in the Channing area of the Panhandle gas field, helium concentration in natural gas in other fields throughout the United States is being compiled. This work is being done on a cooperative basis by the U. S. Bureau of Mines personnel at Amarillo, Texas. No results are yet available, as this part of the project has just been started.

Future plans

Work to be carried forward into the fourth quarter of fiscal year 1952 includes (1) compilation of the subsurface stratigraphy and structure, (2) further examination of cuttings for radioactive materials, (3) further investigation of the distribution of radioactive substances in rock matrix and pores of core material, (4) further development of the radon transport e-

quation, and (5) further compilation, reduction, and mapping of pitot-tube data. Also, the uniqueness of the anomalous helium distribution in the Channing area of the Panhandle field will be tested by the search for the existence or non-existence of similar anomalous distribution in other fields.

Further measurement of the radon content of the natural gas produced in several hundred producing wells within the area of interest will be resumed in June and will be continued throughout the summer. It is anticipated that all producing wells of possible significance can be sampled by the end of the coming field season.

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 now has a W.A.E. appointment with the Geological Survey, is writing the chapter on description of properties; Judith Frondel is preparing a number of descriptive tables; George Switzer of the National Museum is writing chapters on the occurrence and association and the geographic location of uranium; Theodore Botinelly is writing a chapter on characteristic methods of identifying uranium minerals in the field and laboratory. A conference of these people to assay progress was held in Washington in February 1952.

At the end of the quarter analytical work was being done on pure samples of the following uranium minerals:

Studtite	Renardite	Curite
Billietite	Diderichite	A green uraninite
Ianthinite	Orange scholpite	

In addition a pure sample of brannerite from Mono County, Calif. was analyzed for Professor Adolph Pabst of the University of California and 13 samples of different products connected with uranium mineral synthesis studies were analyzed for Professor John Gruner of the University of Minnesota. The results of all this analytical work will be available for inclusion in the monograph.

Judith Frondel, under W.A.E. appointment with the Survey, has been investigating the hydrous uranium oxides. She now has data (not complete) on various properties (optical constants, unit cell constants, chemical analysis dehydration curves, X-ray powder patterns) on pure specimens of becquerelite, billietite, schoepite, paraschoepite, vandendriesschite, ianthinite, masuryite, "mineral X". This work will continue and the data will be available for inclusion in the

monograph.

At the end of the quarter a new and revised edition with corrections and editions of "A glossary of uranium- and thorium-bearing minerals," by Judith Weiss Frondel and Michael Fleischer (U. S. Geological Survey Circular 74, April 1950) was completed in manuscript and should be ready for distribution as a Survey circular toward the end of the next quarter.

Studies of metamict minerals
by Joseph Berman

In the continuing study of metamict minerals, work was done during the quarter on measurements of the d-spacings of heat-treated metamict minerals from X-ray powder photographs. Efforts to index these spacings for the resulting crystalline materials are being made to learn something of the symmetry and structure of the materials.

"High-temperature fergusonite" (see TEI-218, p. 16) has been synthesized from a dry melt and is apparently identical to heated (about 850°C) metamict fergusonite. The equi-molecular proportions of Y_2O_3 and Nb_2O_5 were not actually melted but the temperature was high enough to promote sintering in the mechanically mixed and compressed pellet. Even though melting did not take place, there was complete chemical reaction to form the yttrium niobate from the constituent oxides.

It has been observed in the course of the studies of metamict minerals that many of the recrystallized metamict minerals show minor differences in their d-spacings from specimen to specimen and these differences probably reflect differences in chemical composition. This has been observed in huttonite patterns (resulting from the ignition of metamict thorite) and in the euxenite patterns and is likely to appear in many of the other metamict minerals.