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UNITED STATES GEOLOGICAL SURVEY,

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**SEARCH FOR AND GEOLOGY OF RADIOACTIVE
DEPOSITS**

**Semiannual Progress Report
December 1, 1952 to May 31, 1953**

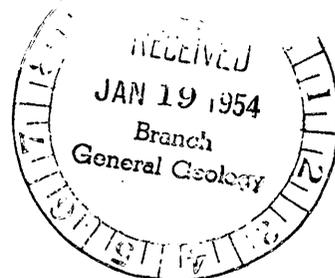
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June 1953



23942

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



GEOLOGY AND MINERALOGY

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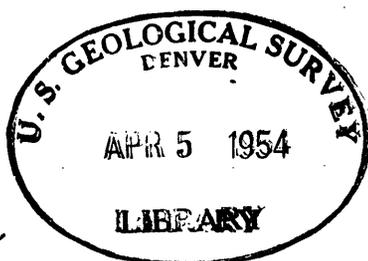
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UNITED STATES DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

SEARCH FOR AND GEOLOGY OF RADIOACTIVE DEPOSITS

Semiannual Progress Report, December 1, 1952 to May 31, 1953*



June 1953

Trace Elements Investigations Report 330

23942

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

CONTENTS

	Page
Summary.....	13
Search for and geology of uranium in sandstone-type deposits.....	24
Colorado Plateau geologic studies.....	24
Introduction, by L. C. Craig and G. W. Weir.....	24
Geologic mapping.....	25
Southwestern Colorado project, by F. W. Cater, Jr.....	26
Carrizo Mountains project, by J. D. Strobell, Jr.....	29 ✓
Monument Valley, Utah project, by D. E. Trimble and R. Q. Lewis, Sr.....	31
Monument Valley, Arizona project, by I. J. Witkind.....	34
Red House Cliffs project, by T. E. Mullens.....	36
White Canyon project, by A. F. Trites, Jr.....	38
Capitol Reef project, by J. F. Smith, Jr.....	40
Photogeologic mapping, by W. A. Fischer.....	43
Stratigraphic studies, by G. A. Williams.....	43
Morrison formation.....	43
Triassic formations.....	47
Ground-water studies, by D. A. Jobin.....	51
Geobotanical studies.....	53
Geobotanical research, by H. L. Cannon.....	53
Geobotanical prospecting, by P. F. Narten.....	55
Resource appraisal.....	58
Ore distribution study, by J. D. Strobell, Jr.....	58
Grade distribution study, by J. D. Strobell, Jr.....	59
Pre-Morrison resource appraisal, by W. I. Finch.....	59
Cenozoic studies.....	61
Mineralogic studies.....	61
General mineralogic studies, by A. D. Weeks and L. B. Riley.....	61
Distribution of elements project, by E. M. Shoemaker...	65
Geophysical investigations, by R. A. Black.....	68
Original-state core studies, by G. E. Manger.....	72
Pumpkin Buttes area, Powder River Basin, Johnson and Campbell Counties, Wyoming, by M. L. Troyer.....	79 ✓
Black Hills, South Dakota, by V. R. Wilmarth.....	81
Silver Reef district, Washington County, Utah, by Frederick Stugard.....	83
Search for and geology of uranium in veins, igneous rocks, and related deposits.....	85
Reconnaissance.....	85
Central Mineral Belt, Colorado, by C. T. Pierson, Q. D. Singewald, and M. G. Dings.....	85
General geologic studies.....	87
Relation of uranium to post-Cretaceous vulcanism, by R. R. Coats.....	87
Zonal relations of uranium deposits in metalliferous districts, by B. F. Leonard.....	88
Wallapai district, Arizona.....	88
Central City district, Colorado.....	89
Radiometric reconnaissance of the Gold Hill mining area, Boulder County, Colorado, by R. H. Campbell....	90

Frequency distribution of uranium with relation to enclosing wall rocks, by J. W. Adams.....	92
District studies.....	93
Colorado Front Range, by P. K. Sims.....	93
Central City district, Gilpin County, by P. K. Sims, A. A. Drake, and R. H. Moench.....	94
Dumont-Fall River area, by F. B. Moore.....	96
Freeland-Larmartine district, by J. E. Harrison.....	96
Summary.....	97
Plans.....	98
Mineralogic, geochemical and petrologic studies, by George Phair and Norman Herz.....	98
Ralston Buttes district, Colorado, by D. M. Sheridan.....	99
San Juan Mountains, Colorado.....	101
Reconnaissance, by C. T. Pierson.....	101
Western San Juan Mountains, by A. L. Bush.....	101
Boulder batholith, Montana, by G. E. Becraft.....	102
Thomas Range, Utah, by F. W. Osterwald.....	104
Placerville hydrocarbons, Colorado, by V. R. Wilmarth.....	107
Garo, Colorado, by V. R. Wilmarth.....	109
Lost Creek, Wyoming, by D. M. Sheridan, J. T. Collier, and C. H. Maxwell.....	110
White Signal-Black Hawk districts, New Mexico, by Elliot Gillerman.....	111
Search for and geology of uranium in carbonaceous rocks.....	114
Reconnaissance.....	114
Eastern states, by S. W. Welch and J. W. Huddle.....	114
Western states.....	116
New Mexico, by G. O. Bachman, E. H. Baltz, Jr., and R. B. O'Sullivan.....	116
Parts of Colorado, Utah, Idaho and Wyoming, by J. D. Vine.....	117
Parts of Colorado, Wyoming and Montana, by J. R. Gill..	118
California and adjacent states, by G. W. Moore.....	119
Mineralogy and geochemistry of carbonaceous rocks, by I. A. Breger, M. Deul, R. Meyrowitz, and S. Rubinstein.....	121
Uraniferous coals.....	121
Miscellaneous carbonaceous substances.....	121
Black shale, by I. A. Breger, M. Deul, and S. Rubinstein....	122
District studies.....	123
Dakota region, by J. R. Gill.....	123
Uranium minerals in Cedar Canyon, Harding County, South Dakota, by J. R. Gill.....	124
Coal petrographic studies on Dakota lignite, by J. M. Schopf, R. J. Gray, and J. C. Warman.....	125
Goose Creek district, Cassia County, Idaho, by W. J. Mapel..	138
Red Desert area, Sweetwater County, Wyoming, by H. Masursky.	140
Fall Creek area, Bonneville County, Idaho, by J. D. Vine....	142
Coyote mining district, by H. D. Zeller and E. H. Baltz, Jr.	143
Miller Hill area, by J. D. Vine.....	143

Black shale investigations.....	144
Reconnaissance.....	144
Chattanooga shale investigations, by L. C. Conant.....	145
Organic matter of the Chattanooga shale, by J. M. Schopf.....	146
Uranium in asphaltites.....	152
Reconnaissance for uranium-bearing asphaltites, by W. J. Hail.....	152
Core processing, by J. M. Schopf.....	153
Cores of Dakota lignite.....	153
Cores of Chattanooga shale from the Youngs Bend area in central Tennessee.....	154
Samples from other sources.....	158
Search for and geology of uranium in phosphate.....	160
Northwest phosphate, by R. W. Swanson.....	160
Phosphoria formation in southeastern Idaho and western Wyoming, by V. E. McKelvey, R. W. Swanson, and R. P. Sheldon.....	161
Progress report on investigations of western phosphate deposits, by R. W. Swanson, V. E. McKelvey, and R. P. Sheldon.....	162
Stratigraphy of the Phosphoria formation in northwestern Wyoming, by R. P. Sheldon.....	162
Stratigraphy of the Phosphoria formation in part of southwestern Montana, by E. R. Cressman.....	163
Permian phosphate deposits of Montana, by R. W. Swanson....	164
Preliminary report on geology of Centennial Range, Montana-Idaho, phosphate deposits, by F. S. Honkala.....	164
Control of rare element concentrations in sea water, by K. B. Krauskopf.....	165
Southeast phosphate.....	166
Geologic studies, by C. B. Hunt and J. B. Cathcart.....	166
Southeast phosphate mineralogic and petrologic studies, by Z. S. Altschuler.....	171
Alteration studies.....	171
Field work.....	175
Phosphate studies in the eastern Gulf of Mexico, by H. R. Gould.	176
Search for and geology of thorium and monazite deposits, by J. C. Olson.....	180
Southeastern coastal plain, by Lincoln Dryden.....	181
District studies.....	184
Southeastern monazite exploration, by W. C. Overstreet.....	184
Wet Mountains, Colorado, by Q. D. Singewald and R. A. Christman.....	187
Lemhi Pass, Idaho-Montana, by W. N. Sharp and W. S. Cavender.....	188
Powderhorn district, Gunnison County, Colorado, by J. C. Olson.....	190
Mineral Hill district, Lemhi County, Idaho, by W. N. Sharp.....	192

Regional reconnaissance for uranium and thorium in the United States..	195
Northeast district, by F. A. McKeown and H. Klemic.....	195
Southeast district, by H. S. Johnson.....	198
South-central district, by J. W. Hill.....	200
North-central district, by R. C. Vickers.....	204
Huron River pitchblende occurrence, Baraga County, Michigan.	204
Leitch and Isham uranium claim, Dickinson County, Michigan..	206
Nepheline syenite complex, Marathon County, Wisconsin.....	206
Other areas.....	207
Colorado-Wyoming district, by R. U. King and E. P. Beroni.....	208
Southwest district, by R. B. Raup, Jr.....	213
Utah-Nevada district, by A. O. Taylor.....	217
Northwest district, by F. C. Armstrong.....	221
Central Idaho placer deposits.....	221
Crescent mine, Shoshone County, Idaho.....	222
Lemhi Pass thorium deposits.....	222
Plans.....	223
California district, by G. W. Walker.....	224
Regional reconnaissance for uranium and thorium in Alaska,	
by Helmut Wedow.....	226
Reports on results of reconnaissance in 1952.....	227
Plans for June 1-November 30, 1953.....	227
Analytical service and research on methods.....	230
Service, by Jack Rowe.....	230
Research.....	231
Radiometry.....	231
Thorium analysis, by W. R. Champion, F. J. Flanagan,	
and F. E. Senftle.....	231
Spectrography, by C. L. Waring.....	231
Chemistry.....	233
Stabilities of dilute solutions of U, Th, and Pb on	
storage in glass and polyethylene bottles,	
by R. G. Milkey.....	233
New transmission fluorimeter for solutions.....	233
The determination of micro amounts of P ₂ O ₅ in the	
presence of As, Si, and Ge, by H. Levine and	
F. S. Grimaldi.....	234
Zirconia dishes in fluorimetric uranium analysis,	
by F. Cuttitta and F. S. Grimaldi.....	234
A study of the flame photometric determination of	
calcium in "leached zone" samples by Lillian Jenkins.	234
Note on the determination of selenium in rocks which	
contain organic matter, by E. J. Hackney.....	235
Determination of aluminum in leached zone samples,	
by M. Delevaux.....	236
Bibliographic work, by F. Cuttitta.....	237

Geochemical and petrological research on basic principles.....	238
Distribution of uranium in igneous complexes, by E. S. Larsen, Jr.	238
Age.....	239
Distribution of radioactivity in minerals of rocks.....	241
Distribution of radioactivity in rocks of a petrographic province.....	242
Distribution of radioactivity in petrographic provinces.....	242
Weathering, transportation, and redeposition of uranium, by R. M. Garrels.....	242
Synthesis of uranium-bearing minerals, by Irving Friedman.....	245
Isotope geology.....	252
Isotope geology of the Colorado Plateau, by L. R. Stieff, T. W. Stern, R. A. Powell, and H. Mela, Jr.....	252
Diffusion studies, by J. T. Bracken and F. E. Senftle.....	253
Instrumentation, by I. Friedman, L. R. Stieff, M. D. Lee, H. Allen, and A. R. Nelson.....	254
Isotope geology of lead, by R. S. Cannon, Jr.....	254
X-ray crystallography, by H. T. Evans, Jr.....	260
Uranium mineral structures.....	262
Parasite problem.....	263
Publications.....	263
Radon and helium studies, by G. B. Gott, G. E. Manger, and H. Faul.....	264
Uraniferous asphalts.....	265
Analyses of core samples.....	265
Transient gas flow problem.....	270
Plans.....	270
Mineralogic and petrographic service and research, by E. J. Dwornik....	272
Service.....	272
Identification.....	272
Public sample program, by E. Williams and R. Thompson...	272
Special samples, by R. Kellagher.....	272
Monazite sands, by J. Stone.....	272
X-ray, by C. L. Christ.....	273
Electron microscopy, by E. Dwornik and C. Davis.....	273
Research.....	274
Mineral separation and petrographic methods, by R. Kellagher, and P. Benson.....	274
Properties of uranium-bearing minerals, by J. C. Rabbitt....	275
Geophysical prospecting services and research on methods.....	279
Development and maintenance of radiation detection equipment, by W. W. Vaughn.....	279
Airborne radioactivity surveying, by R. M. Moxham.....	280
Areas surveyed.....	282
Discussion of significant areas.....	282
Atlantic Ocean beach survey.....	282
Florida phosphate survey.....	286
Shelby quadrangle.....	288
Absorption and scattering of gamma radiation.....	288
Plans.....	289

Physical behavior of radon, by A. S. Rogers.....	293
Absorption and scattering of gamma radiation, by A. Y. Sakakura.	297
Gamma-ray logging, by K. G. Bell.....	298
Routine logging service.....	298
Colorado Plateau.....	298
Tyrone and Blackhawk districts, New Mexico.....	299
Interpretation and processing of data.....	299
Development.....	300
Resource studies.....	301

ILLUSTRATIONS

Figure	Page
1. Index map of part of the Colorado Plateau, showing location of mapping projects.....	27
2. Index map showing progress of photogeologic mapping in the Colorado Plateau area.....	44
3. Index map showing scheduled photogeologic mapping for fiscal 1954-55.....	45
4. U. S. Bureau of Mines core analysis for hole drilled on the Colorado Plateau.....	74
5. Index map of White Signal district, Grant County, New Mexico.....	112
6. Geologic sketch map of Cedar Canyon carnotite deposit, Slim Buttes, Harding County, South Dakota.....	126
7. Sketch map of part of U.S.G.S., Slim Buttes exploration area.....	127
8. Summary P/M/G results, hole 3, Slim Buttes area, Harding County, South Dakota.....	129
9. Summary P/M/G results, hole 16, Slim Buttes area, Harding County, South Dakota.....	130
10. Summary P/M/G results, hole 17, Slim Buttes area, Harding County, South Dakota.....	131
11. Summary P/M/G results, hole 18, Slim Buttes area, Harding County, South Dakota.....	132
12. Mendenhall coal bed hole 16, Slim Buttes area, South Dakota...	137
13. Index map showing location of Goose Creek district.....	139
14. Sketch map showing results of exploratory core drilling in 1952 and area to be tested by drilling in 1953, Red Desert area, Sweetwater County, Wyoming.....	141
15. Summary P/M/G results, hole SD-10, Slim Buttes area, Harding County, South Dakota.....	155
16. Summary P/M/G results, hole SD-19, top part, Slim Buttes area, Harding County, South Dakota.....	156
17. Summary P/M/G results, hole SD-19, lower part, Slim Buttes area, Harding County, South Dakota.....	157
18. Index maps of Lemhi Pass area, Idaho-Montana.....	189
19. Sketch map of Powderhorn district, Gunnison County, Colorado..	191
20. Index maps of Mineral Hill monazite district, Lemhi County, Idaho.....	193
21. Map of Colorado showing localities examined for uranium and thorium.....	209
22. Map of Wyoming showing localities examined for uranium and thorium.....	210
23. Index map of Utah and Nevada showing localities examined for radioactive materials during fiscal year 1953.....	218
24. Localities in Alaska to be examined for uranium deposits in 1953.....	229
25. Distribution of uranium in rocks of the Southern California batholith.....	243

Figure	Page
26. Graph of V_2O_5/KOH ratio, phase boundaries at $17^\circ C$	246
27. Graph of V_2O_5/KOH ratio, phase boundaries at $25^\circ C$	247
28. Graph of V_2O_5/KOH ratio, phase boundaries at $30^\circ C$	248
29. Graph of V_2O_5/KOH ratio, phase boundaries at $35^\circ C$	249
30. Graph of V_2O_5/KOH ratio, phase boundaries between 40° and $60^\circ C$	250
31. Graph of V_2O_5/KOH ratio, phase boundaries between 60° and $90^\circ C$	251
32. Alpha tracks on nuclear emulsions showing radioactivity concentrated in asphaltic material.....	266
33. Airborne radioactivity survey projects.....	283
34. Airborne radioactivity surveys in South Carolina.....	284
35. Airborne radioactivity surveys in Georgia.....	285
36. Airborne radioactivity surveys in Florida.....	287
37. Graph showing distribution ratio for radon.....	294

TABLES

Table	Page
1. Core analysis and radioactivity data drill hole LP-530, Uravan district, Montrose County Colorado.....	75
2. Results of ash, oil assay, uranium and spectrographic determinations of matrix and hand picked organic matter (<u>Foerstia</u>).....	150
3. Results of organic element microanalysis of <u>Foerstia</u>	151
4. Heavy-mineral contents of overburden sands and aluminum phosphate zone in the Jaynee Jay mine, Florida.....	174
5. Analytical work and sample inventory, Dec. 1952 to May 1953.....	230
6. Age determinations of selected igneous rocks.....	240
7. The distribution of uranium in ppm in minerals of two rocks from Southern California.....	241
8. Variations between measured Pb-isotope ratios of galena samples (maximum range in variation of ratio, expressed as percent).....	257
9. Results of analyses of core samples from a gas well in Moore County, Texas.....	268
10. Areas proposed for airborne radioactivity surveys.....	290
11. Brine samples from Panhandle and Hugoton gas fields.....	296

SEARCH FOR AND GEOLOGY OF RADIOACTIVE DEPOSITS

SEMIANNUAL PROGRESS REPORT

December 1, 1952 to May 31, 1953

SUMMARY

Uranium in sandstone-type deposits.---Two of the projects of the geologic mapping program, the southwestern Colorado and Carrizo Mountains projects, continued map compilation and report preparation during the period of this report. Mapping in southwestern Colorado has shown that there are concentrations of uranium ore deposits along the flanks and axes of salt anticlines beyond the limits of the Uravan mineral belt. Mapping in the Carrizo Mountains has shown that the ore horizon in the Salt Wash sandstone member of the Morrison formation may depend on the thickness or composition of the sandstone or may depend on some controlling factor superposed upon the Salt Wash, such as a former water table, that may be related to the uplift of the mountains.

The geologic mapping projects in Monument Valley, Ariz. and Monument Valley, Utah, are completed and final reports are being prepared. In Monument Valley, Ariz., the ore deposits are dominantly in channels at the base of the Triassic Shinarump conglomerate; 58 channels were recognized, 17 of which have exposures of mineralized rock. In Monument Valley, Utah, uranium ore occurs mainly in channels in the Shinarump, but anomalously high radioactivity was also noted in the Triassic Chinle formation.

Geologic mapping at White Canyon, Capitol Reef, and Red House Cliffs in Utah is partially completed and will be continued during the summer of 1953. At White Canyon most of the uranium deposits are in the Shinarump conglomerate. Three types of deposits related to the grain size of the enclosing Shinarump beds are recognized: (1) relatively continuous high grade ore bodies found in coarse sandstone, (2) ore bodies composed of high grade areas separated by low grade areas found in channel-fill conglomerate, and (3) sparse but relatively continuous low grade deposits found in siltstone or very fine-grained sandstone. In the Capitol Reef area most of the radioactive rock is in a claystone layer at the base of the Shinarump conglomerate in channels cut into the underlying Moenkopi formation. In the Red House Cliffs area the probability of finding uranium ore in the part of the area mapped to date is low because few favorable beds are exposed. Uranium resources have been appraised in each mapped area and geologic guides to ore have been suggested. Recommendations for geophysical work and drilling are being considered for favorable areas in Monument Valley, Ariz., Monument Valley, Utah, and White Canyon, Utah.

During the reporting period the stratigraphic studies program compiled data and prepared reports. Based on study of regional petrology the Morrison formation probably had three general source areas: (1) central New Mexico, (2) west and southwest of south-central Utah, and (3) west or northwest of central Utah. The uranium deposits of the Salt Wash member in the Uravan mineral belt lie within an area which has received a significantly larger than average amount of potassium feldspar and volcanic debris from the western source during the deposition of the Salt Wash member. Tentative correlation of Permian formations and members have been made over a broad area in southern Utah and northern Arizona. The ore-bearing Triassic Shinarump conglomerate is essentially a discontinuous basal conglomerate of the Chinle formation; the Shinarump shows regional differences in thickness and dimensions of channels at its base. Regional study of the Upper Triassic Chinle formation shows that it can be divided into several members and units; some of these units are local, whereas others are found throughout northern Arizona and southern Utah.

As part of the ground-water studies program, work was begun on the problem of determining the horizontal and vertical transmissibility of the exposed sedimentary formations on the Colorado Plateau.

The geobotanical studies program was engaged mainly in report writing during this period. Short geobotanical reconnaissance studies were made in Lisbon Valley, Utah; Paradox Valley, Colo.; Gypsum Valley, Colo.; the Inter-river area, Utah; and the Circle Cliffs area, Utah. Additional work was recommended in the Paradox Valley, Colo., and in the Circle Cliffs area, Utah. Geobotanical prospecting at Grants, New Mexico has proven useful in extending known mineralized areas and has suggested areas for further prospecting. A geobotanical prospecting project was begun on Deer Flats, Utah.

The resource appraisal program has been engaged in compiling data and preparing reports. Pre-Morrison reconnaissance studies have outlined three belts of ground on the Plateau that are favorable for better than average deposits. Preliminary results of a study of modern stream gravels indicate that anomalously high radioactivity in modern stream gravels may be a useful prospecting aid under certain restricted conditions.

Review and synthesis of the literature and field study of Cenozoic geologic features of the Colorado Plateau suggest that the intrusive igneous rocks of the Plateau are late Tertiary and are much younger than the lead-uranium ages determined for uranium deposits.

The mineralogic studies program continued to identify and describe minerals of the uranium deposits of the Colorado Plateau. Studies of clays and clay minerals from the Colorado Plateau are in progress. At least some of the "vanadium clay-like" mineral from Placerville, Colo. has been shown to be true roscoelite. Study of the mineralogy of the Monument No. 2 mine suggests that uranium and vanadium minerals as originally deposited were generally separate, and were combined only

after oxidation. Work by the distribution-of-elements project suggests that metallic elements are distributed systematically in uranium ore bodies and that the correlation between the metals can be related to the geologic environment of the ore bodies. The average composition of the Salt Wash sandstone was found to be close to the average composition of 32 formations from the Colorado Plateau ranging from pre-Cambrian to late Cretaceous. Comparison of minor elements in bedded uranium deposits of the Colorado Plateau with barren "ore zone" sandstone indicates that certain elements, in addition to uranium and vanadium, are concentrated in the ore deposits.

The district studies project of the geophysical investigations program has been computing data and preparing reports during the last six months. Results of geophysical investigations on the Gramlich Group, Colo., show that the geologically favorable area for uranium deposits is defined by a broad near-uniform zone of higher resistivity than in geologically less favorable areas, and that the uranium deposits are associated with self-potential negative anomalies. Resistivity methods proved applicable in delineating channels in the Koley Black area, Monument Valley, Ariz. A self-potential survey at the Happy Jack mine, Utah, showed small anomalies that may be associated with sulfide concentrations. Seismic refraction tests to help locate channels in the Shinarump conglomerate have not proved generally applicable. Results of electric well-logging operations in southwestern Colorado and southeastern Utah suggest strong contrasts between unfavorable, favorable, and mineralized rock.

Studies made during the period of original-state cores from the Colorado Plateau have provided basic data on the physical and chemical properties of rock where the interstitial water has not been changed radically by the flushing action of drill water. The investigations include: (1) elastic constant determinations by the Bureau of Mines; (2) porosity, permeability, and interstitial water determinations by the Bureau of Mines; and (3) mineralogic and petrographic examination of well-mineralized parts of the core. Among the conclusions reached in the studies to date are: (1) the more radioactive samples, particularly those from the ore zones, show a high percent of saturation in the pore space which may be due to "water of crystallization" from clay-like minerals associated with the ore; and (2) the low chloride content of the interstitial water indicates that it was not derived from normal sea water nor indirectly from brackish water. Further work will be done on original-state cores during fiscal 1954.

In the Black Hills of South Dakota, detailed studies have shown that the Lakota sandstone contains two principal ore-bearing zones, about 50 feet apart stratigraphically, in the Long Mountain area. In the lower zone, a massive basal sandstone, the uranium content ranges from 0.039 to 0.47 percent and the V_2O_5 content from 0.11 to 0.75 percent; the content of the upper zone is on the same order for both uranium and vanadium. Preliminary study of cores from the Edgemont area have been completed; comparison of these cores with specimens from mines in the area may result in a determination of the paragenesis of the ore.

Work in the Silver Reef district, Washington County, Utah, will be terminated by the end of fiscal 1953. The district has produced approximately 500 tons of ore having an average grade of 0.29 percent U and 1.65 percent V_2O_5 ; but operations are decreasing in scale and it is increasingly difficult to mine the ore at a profit.

Uranium in veins, igneous rocks, and related deposits.---Studies of the relation of uranium to post-Cretaceous vulcanism point to a correlation between the uranium content of igneous rock bodies and the content of elements known to be enriched by pegmatitic processes. There is also an indication of a broad regional pattern in the grouping of most of these elements. Field work during fiscal 1954 will investigate further this pattern of regional distribution.

Geologic prospecting guides to areas favorable for the occurrence of uranium deposits were studied in the Wallapai district, Ariz., the Central City district, Colo., and the Gold Hill mining area, Colo. The significant radioactive deposits at Wallapai appear to be in areas where the metalliferous veins have a high or unknown Cu/Pb ratio and an intermediate or unknown Au/Ag ratio; this conclusion is tentative because of the sparse data upon which it is based. At Gold Hill nearly all the veins were from 0.01 to 0.03 mr/hr higher in radioactivity than the country rock surrounding them. The most promising parts of the district, based on investigations to date, are in the group of telluride-sulfide veins peripheral to the northwestern "gold center" of the field.

At the East Calhoun mine in the Central City district, Colo., a small pod of high-grade pitchblende ore was encountered, the highest assay being 9.94 percent U. Pitchblende has also been identified from three mine dumps and from several mines in the district.

Exploration work at the Martha E mine, Clear Creek County, Colo., financed by DMEA, was completed May 15 with the sinking of an inclined winze 85 feet deep and drifting and crosscutting from the bottom of the winze. Torbernite, metatorbernite, autunite, and sooty pitchblende occur in lenses and pods along the vein, which appears to become stronger with depth. In the Ralston Buttes district, Jefferson County, Colo., several investigations have been made and a district-type study is planned for fiscal 1954. Pitchblende is known from eight localities in the district. The Ralston Buttes district also contains beryl-chrysoberyl deposits which will be investigated.

In the Placerville district, Colo., a study is being made of the relationship of radioactive and non-radioactive hydrocarbons to the base metal-sulfide vein deposits and the bedded uranium-vanadium-chromium deposits. The hydrocarbon occurs as fracture fillings, in fault zones, and as disseminations in sedimentary rocks. The hydrocarbon in the fracture fillings contains as much as 0.078 percent eU and the hydrocarbon ash contains from 0.034 to 0.33 percent U; the ash content ranges from 0.54 to 17.0 percent. Hydrocarbons from the fault zones, and the disseminated hydrocarbon, contain as much as 9 percent U. The uranium

content of the hydrocarbon ash ranges from 0.64 to 9.8 percent; the ash content from 13 to 30.1 percent. The common trace-metal constituents in the hydrocarbon are Ag, Co, Cr, Cu, Mo, Ni, Pb, V, and Y. In general the hydrocarbon ash that is rich in uranium also is relatively high in Cu, Pb, Mo, and Y.

At the Shirley May deposit near Garo, Park County, Colo., mining is being carried on in two beds, 50 to 150 feet apart stratigraphically. The ores consist of (1) sandstone in which tyuyamunite is the principal ore mineral, and (2) sandstone which contains intermixed uranium, vanadium, and copper minerals. The average grade of the ore produced from both beds is 0.16 percent U and 0.72 percent V_2O_5 . The uranium content of samples from the mine ranges from 0.001 to 0.48 percent U.

Uranium deposits in carbonaceous rocks.—Reconnaissance of coals in Pennsylvania has found that the lower few inches of the Freeport coal and the upper few inches of the associated underclay in the vicinity of Darlington, Beaver County, contains about 0.005 percent eU. At one place, the upper 3 inches of the underclay contain 0.01 percent eU. In Ohio, the Middle Kittanning coal at one place in Carroll County, contains 0.002 percent eU and the Pittsburgh coal at one place in Belmont County contains 0.003 percent eU. These localities will be studied in greater detail and reconnaissance is continuing.

No deposits of potential commercial interest were discovered by reconnaissance in New Mexico but minor amounts of radioactivity were detected at the following localities: Canyon Mulatto, Hosta Butte, Satan Pass, Mariana Pass, and Dalton Pass, all in McKinley County. The richest material found was at Hosta Butte, where coaly shale contains 0.033 percent U in the ash. In Idaho, coal in the Bear River formation contains 0.03 percent U in the ash in the Caribou Mountains, Bonneville County, and 0.009 percent U in the ash in Driggs County. Fresh bituminous sandstone in the Vernal area, Utah contains only very small amounts of uranium. In Wyoming, coaly shale in the Bridger formation in southwestern Sweetwater County contains 0.012 percent U in the ash. A 4.8-foot coal bed in the Lakota formation in the Cambria coal field, Weston County, contains 0.012 percent U in the ash. Other coal beds, which have been mined in the past, were non-radioactive. In Colorado, an impure coaly shale in the Belden formation, Gunnison County, and a carbonaceous shale in the Laramie formation, Larimer County, each contain 0.006 percent U in the ash.

The Ekalaka lignite field, Carter County, Montana, contains an 8-foot lignite bed in which the average content in the ash is 0.017 percent. The most highly uraniferous part of a 1.5-foot bed contains 0.14 percent U in the ash. Detailed mapping of part of the Ekalaka Hills will be completed this field season.

A 6-inch bed of lignite near Newhall, Los Angeles County, California, contains 0.02 percent U, 37.7 percent ash, and 0.054 percent U in the ash. No other coal outcrops were found in the vicinity. Lignite in the Ione field, Amador County, is mined for the production of montan wax and other

industrial chemicals. The upper 9 inches of the 12-foot zone of lignite contains 0.004 percent U. Asphaltic sandstone near Edna, San Luis County, contains 0.002 percent U. The asphalt amounts to 10 percent of the sandstone.

Drilling by the Bureau of Mines in the Mendenhall area, Harding County, South Dakota, is about three-fourths complete, 29 of a planned 38 holes having been drilled. The uranium content of the coal in the drill holes is about the same as found on surface outcrops in holes drilled by the Geological Survey. The mineralized part of the Mendenhall bed is about 5 feet thick and the average uranium content of the ash ranges from 0.018 to 0.03 percent. Intervals about a foot thick at the top of the bed contain, in some holes, as much as 0.35 percent U in the ash.

Geologic work in connection with the drilling program in the Mendenhall area discovered a carnotite deposit in channel sandstone at the top of the White River formation. The sandstone contains fossil roots and stems and the carnotite is concentrated near this plant material and also on fracture planes. The carnotite is exposed along the outcrop for about 130 feet and is disseminated in the sandstone through thicknesses of 2 to 6 feet. The only analyses available are of two grab samples that contain 0.08 and 0.23 percent U. A detailed report is being prepared. Shallow core holes will be necessary to determine the extent of the carnotite behind the outcrop.

Drilling has begun in the Fall Creek area, Bonneville County, Idaho, to obtain additional information on the thickness, grade, and areal extent of uraniferous coal and associated carboniferous rocks and to test the possibilities of finding higher grade material.

Field work is beginning in the Miller Hill area where thin beds of algal limestone contain more than 0.1 percent U. Proposals for drilling will be made as soon as enough geologic work has been done to provide a sound basis for a drilling program.

The Coyote mining district, Mora County, N. Mex., contains uranium-bearing copper deposits from which weathered samples contain as much as 0.067 percent U and average about 3 percent copper. Field work is being resumed and will include large-scale mapping of the most highly mineralized zones and trenching to obtain fresh samples and to determine if both the uranium and copper content increase at depth.

Layer-sampling microscopic study of cores from the Mendenhall area, S. D., is well underway. The petrographic composition of lignite in hole 16 has been determined by this method. No correlation is apparent between uranium content and the distribution of the anthraxylon, translucent attritus, opaque attritus, fusain, and visible impurities that have been recognized in the coal. A series of such studies will be necessary, however, before conclusions can be reached. Cores processed since January 1, consist of two cores from the Bureau of Mines drilling in the Mendenhall area and six cores from the Chattanooga shale drilling in the

Youngs Bend area, central Tennessee. About 250 samples were processed and submitted for chemical analysis. The cores were described in detail and sampled for research. Radioactivity profiles were made for all cores to guide the sampling for analysis and study.

Black shale reconnaissance methods are being revised. Shales believed to be in favorable environments as indicated by literature study will be sampled to test specific geologic features as areas of thinness and areas of overlap on older rocks. Shales of Pennsylvanian age in the Hartville formation in Nebraska and Wyoming, appear promising for this kind of examination.

The Chattanooga shale is being core drilled in cooperation with the Bureau of Mines in the Youngs Bend area, central Tennessee. The 36 holes planned should be completed by July 15.

Uranium in phosphate.---During the past six months much stratigraphic and analytical data were compiled for release as rapidly as possible. Four circulars presenting data on measured sections of the Phosphoria formation were published and companion TEI reports, containing data on the uranium content of the sections, were transmitted to AEC; nine similar pairs are being processed. Geologic maps and structure sections for two areas were placed on open file, and two other comparable maps were completed and are being published. A number of other reports on the Phosphoria formation were made available through various channels.

During the period several valuable deposits were discovered, most noteworthy of which are a 6-foot bed of acid-grade rock in the Centennial Range at the Montana-Idaho state line; a 12-foot bed of 33 percent P_2O_5 rock in the Caribou Range, Idaho; several strippable deposits of furnace grade rock in southeastern Idaho; and a 12-foot bed of 20 percent P_2O_5 rock at the top of the formation north of Cokeville, Wyo. The investigations indicate that the reserves of high-grade phosphate rock in the Centennial Range may total scores of millions of tons.

In connection with the study of the genesis of the phosphatic shales it has been found that the Phosphoria shales are enriched by a factor of at least 2 over both the crust of the earth and average shale, in Ag, V, Pb, Cr, Ni, and Mo. Ions of these other metals have been studied from the standpoint of their precipitation by normal ions of sea water, precipitation as a sulfide, and adsorption by inorganic and organic materials. Preliminary investigation indicates that normal ions of sea water cannot be responsible for the rare metal concentrations, and that various metals are removed either by precipitation as a sulfide or by adsorption. The study is continuing.

In the Southeastern phosphate field a brief survey to test the possible use of geobotanical prospecting in the Florida land-pebble deposits was made during the period. Several contracts to drill areas that will be mined prior to 1965 have been let by the AEC, and drilling is continuing on a fairly large scale. At the present time the Survey's projects

in the district are being reoriented with a view toward providing the AEC, during the next 15 months, with a series of reports that will assemble rather fully, synthesize, and evaluate the data that have been gathered by the work in the land-pebble district of Florida.

Petrologic studies of samples from a mine face at Homeland, Florida, show that a definite sequence of mineralogic associations and successions prevails in all the sections studied. The uranium content shows enrichment where pseudowavellite first appears and apatite is still present; the suggested mechanism is filtering of uranium carried in solution by apatite in the early stages of alteration, when the apatite is soft and highly porous.

In all samples from the Homeland and Jaynee Jay mines where mineralogic studies were carried on, the cumulative curves of grain size distribution were virtually identical, as were heavy-mineral studies of the 250- and 325-mesh fractions of the Jaynee Jay samples. This striking uniformity of grain size seems characteristic of the district.

Results of phosphate studies in the offshore area between Tarpon Springs and Fort Myers, Florida, show that phosphatic sediments are confined to a belt about 20 miles wide which extends from shore to a depth of 10 fathoms. The sediments in this zone are chiefly detrital and generally contain less than 0.50 percent P_2O_5 . Within this zone are several smaller areas of sediment with a higher phosphate concentration (as much as 13.4 percent P_2O_5). The phosphate in these areas appears to have been derived, at least in part, from submarine outcrops of older formations.

Partially phosphatized Foraminifera occurring locally in the inshore zone are Pleistocene to Recent in age. This suggests that phosphate replacement of the tests of these organisms may be in progress today.

Thorium and monazite deposits.---Studies of the Atlantic Coastal Plain placers from North Carolina to Florida have shown that they contain two distinct mineral suites. One, lacking epidote, hornblende, and garnet, is characteristic of all pre-Pleistocene formations and of the older parts of the Pleistocene; the other, containing these minerals, is found in modern beaches and dunes and in some Pleistocene deposits. It has also been found that the titania content in the ilmenite in the old Florida beaches is high, but decreases northward and upstream. The titania content is of primary importance in determining whether or not a deposit is workable economically.

The Wet Mountains thorium area, Colo., which is being explored by the Survey, has now attracted the attention of private companies, that have leased several of the more promising properties.

At least 30 deposits of thorium-bearing minerals have been discovered since 1950 in the Powderhorn district, Gunnison County, Colo. The deposits are in an area of about 70 square miles, and are apparently related to alkalic dike rocks such as augite, syenite and shonkinite. The Little Johnny claims, which were examined late in May in connection with an application for a DMEA loan, have been leased by the Rare Earth Mining Company,

Placerville, Colo. Samples indicate that the vein may contain an average of about 0.5%ThO₂, which occurs as thorite and hydrothorite.

Reconnaissance in the Mineral Hill district, Lemhi County, Idaho, in the 1952 field season, indicates that the area contains considerable monazite, and a more complete study will be made in fiscal 1954. Some development work is now being carried on in the district by the Simplot Company of Boise, Idaho.

Regional reconnaissance for uranium and thorium in the United States.--A radiometric reconnaissance of part of the nepheline-syenite complex near Wausau, Marathon County, Wis., disclosed two significant anomalies over thin soil. The anomalies are believed to be caused by thoron or radon seeping upward along a fracture system or by a concentration of radioactive materials along fractures.

The Shattuck Denn Mining Corporation property 18 miles north of Grants, N. Mex., has produced more than 7,000 tons of approximately 0.18 percent U ore from the Recapture member of the Morrison formation. Exploration with DMEA assistance of the ore horizon ~~of~~ the mesa back of the working face has been recommended on the basis of good geologic possibilities.

The placer deposits of central Idaho are growing in importance as a possible source of radioactive minerals. It is reported that two bucket-line dredges are to be brought into Bear Valley, Valley County, where uranium occurs in samarskite, euxenite, and other "radioactive blacks". It is expected that both the uranium and columbium can be recovered from this operation. A columbite placer deposit will be worked this summer in Elmore County, and "radioactive blacks" may be found in that area also.

Geophysical prospecting.--As a result of airborne radioactivity surveys during the period, several areas were located in which uranium and thorium were not hitherto known to occur.

For ten areas surveyed in Florida, eight radioactivity anomalies were recorded, two of which, upon field examination, show uraniferous phosphatic material to be the source of the anomalous radioactivity. Several of these areas may represent hitherto unrecognized extensions of the phosphate deposits in Florida. Twenty areas of abnormal radioactivity, some new and some previously known, were found in the survey of the Atlantic Ocean beach; field examination showed that thorium-bearing (?) minerals associated with "black sands" were the source of the anomalous radioactivity.

Experiments on the physical behavior of radon, undertaken to determine how and why radon moves in rocks and soils, indicate that there are no differences in the distribution of radon in any combinations of air, argon, nitrogen, distilled or domestic waters; and the distribution of radon between distilled water and air does not depend on radon content through a range of 13 to 5,250 micro-microcuries per liter. It was also noted that some streams draining the Wasatch Mountains near Salt Lake City, Utah, show a high radon content, ranging from 14 to 28.5 micro-microcuries per liter. An attempt will be made to trace the radon in these streams to its source.

During the period of November 23, 1952 to May 17, 1953, gamma-ray logs were made of 922 holes, totalling 200,400 feet, drilled by the Colorado Plateau Exploration project through the carnotite-bearing Salt Wash member of the Morrison formation in the Colorado Plateau. Eight additional holes totalling 784 feet, drilled by private companies in the Plateau, were also logged. In the Tyrone and Blackhawk districts, N. Mex., 177 holes, totalling 84,502 feet, which were drilled by private companies, were also logged.

Analytical service and research on methods.---Statistical studies of the precision and accuracy of routine measurements of radioactivity have been made; these studies have led to the use of a standard counting time of two minutes instead of one minute.

Standard deviation and bias of chemical and radioactivity analyses of Florida phosphate samples were determined to be ± 0.00223 percent and $- 0.00023$ percent (indicating that the radioactivity determination is higher).

A method of automatic scanning of simple spectrograms is now being tested; it is designed to reduce eye fatigue and human error.

A rapid (one per man per week) method of making age determinations of fresh igneous rocks older than Cretaceous has been developed as a part of the study of the distribution of uranium in igneous rocks. The ratio of Pb in zircon to the activity apparently gives a reliable and reproducible age determination. Studies of uranium content of minerals in rocks indicate that zircon contains many times more uranium than any of the other minerals of the rocks of the Southern California batholith.

Theoretical studies of the thermodynamic relations among the low valence black "primary" ores of the Colorado Plateaus indicate they are stable under reducing conditions and the high valence uranium and vanadium compounds are stable under oxidizing conditions. The geologic implication that the "carnotite" ores are derived from the "primary" ores by weathering will be tested in the field and in the laboratory.

Synthetic study of the stability fields of potassium-vanadium compounds, as a preliminary to the study of potassium-uranium-vanadium compounds such as occur in the "carnotite" ores, is near completion.

Isotopic analyses of the lead in 30 galena samples shows that there is an appreciable variation in the isotopic composition of lead not only from different geographical locations, but also in the lead from different growth layers in the same crystal. Major environmental differences may or may not be related to variations in the isotopic composition.

Correlation of the synthetic potassium-vanadium compounds with natural minerals and a determination of the structure of hummerite by X-ray crystallographic methods has been completed. A chain structure is present in the mineral and this chain is apparently present in pentavalent vanadium oxy-compounds.

A multiple cone-and-funnel sampler was devised for preparing splits approximating 2 percent of the original sample for immersion work. Preliminary tests indicate the 2 percent split is representative of the entire sample.

SEARCH FOR AND GEOLOGY OF URANIUM IN SANDSTONE-TYPE DEPOSITS

Colorado Plateau, geologic studies

Introduction

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

In 1947 the Geological Survey began a program of geologic studies on the Colorado Plateau on behalf of the AEC. The principal objectives of these studies are to determine the distribution and character of the uranium deposits; the distribution and character of areas favorable for the occurrence of concealed deposits; the mineral habits, origin, and other geologic relations that may be useful in ore-finding; and to appraise the uranium resources of the Colorado Plateau region.

The scope of the geologic studies is comprehensive and their objectives are long-range. The geologic studies program runs the gamut of geologic specialties and ranges from projects with an immediate service function to long-range academic studies of indirect economic importance. With this approach, and through coordination and collation of all work, it is hoped to acquire sufficient geologic knowledge to permit sound guidance of exploration of broad areas for hidden deposits. The studies are intended to provide the maximum possible insurance against a decrease of uranium production that might result from the depletion of current reserves found at the outcrop or by shallow drilling.

The approach and scope of this work is consistent with the Survey's traditional role of geologic investigations. It serves to supplement rather than duplicate the geologic reconnaissance and detailed studies of individual deposits that is being done by the Grand

Junction Exploration Division of AEC, and which is focused primarily on available supplies of raw materials and satisfying short-range requirements.

The Plateau geologic studies include geologic mapping, stratigraphic studies, groundwater studies, geobotanical studies, resource appraisal, mineralogic and distribution-of-elements studies, geophysical investigations, and investigations of Cenozoic geologic history.

Geologic mapping

The geologic mapping projects are aimed at appraising the ore deposits in the main uranium-bearing formations of the Colorado Plateau region, the Morrison formation of Jurassic age and the Shinarump conglomerate and adjacent formations of Triassic age. Work on the Jurassic Entrada sandstone is described as part of the San Juan Mountains project, in the section on uranium in veins and related deposits.

The Morrison mapping projects are nearing completion and geologic mapping of areas of Shinarump conglomerate range from the planning stage to nearly completed projects.

The geologic mapping projects fall into two categories: strip mapping projects and quadrangle mapping projects. Strip mapping involves the detailed study and mapping of only the ore-bearing beds and adjacent strata; it is undertaken only in those regions where a complete and adequate geologic map already exists. Quadrangle mapping involves not only the detailed study and mapping of the ore-bearing beds and adjacent strata but also the extension of geologic mapping to the boundaries of quadrangles as a step toward complete understanding of the geology of the region. The capacity to complete quadrangles and to provide maps in areas away from the immediate

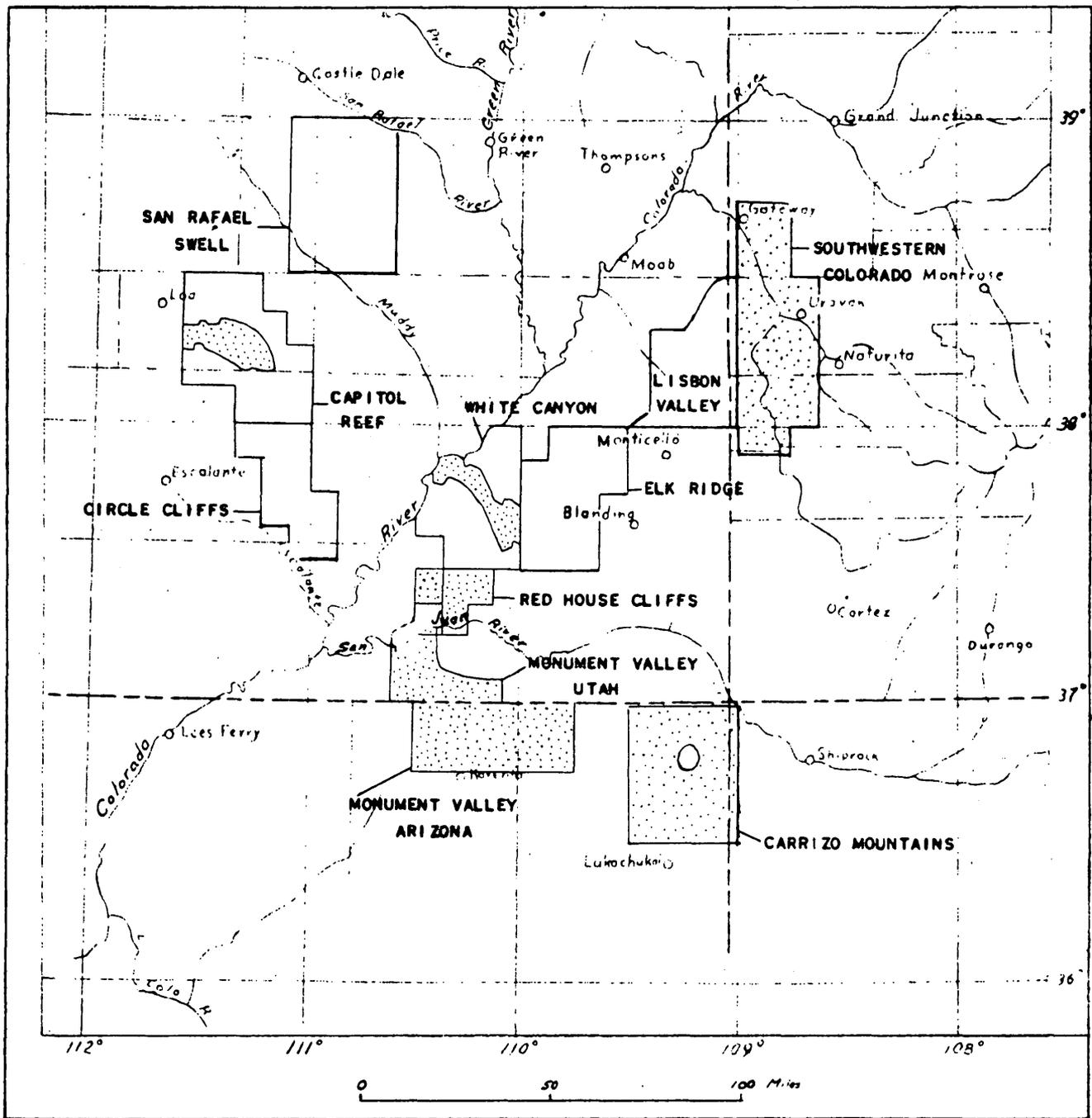
vicinity of ore-bearing beds is provided by Geological Survey funds.

During this reporting period the following projects were active: Southwestern Colorado; Carrizo Mountains, Ariz.; Monument Valley, Ariz.; Monument Valley, Utah; Red House Cliffs, Utah; White Canyon, Utah; and Capitol Reef, Utah. Quadrangle mapping of the Elk Ridge area, Utah, and strip mapping in the San Rafael Swell, Utah, will begin in June or July 1953. During the 1953 field season preliminary geologic reconnaissance probably will be made in the Lisbon Valley area, Utah-Colo. and perhaps in the Circle Cliffs area, Utah.

The Geological Survey is beginning a geologic mapping project along Comb Ridge, San Juan County, Utah under the direction of J. D. Sears and financed entirely by Geological Survey funds. The main purpose of the project is to train younger Survey geologists in mapping techniques. The quadrangles that were selected will complete the map coverage of the Triassic beds around the Monument upwarp. Four $7\frac{1}{2}$ -minute quadrangles arranged in a north-south line along Comb Ridge will connect the completed mapping of the Monument Valley, Ariz. project and the area covered by the new mapping project on Elk Ridge, Utah. Reports for the Trace Elements series will be prepared by the Comb Ridge project and will afford an appraisal of uranium possibilities of the east margin of the Monument Valley upwarp.

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

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



EXPLANATION

- Area to be mapped
- Mapping completed, May 31, 1953

Fig. 1—Index map of part of the Colorado Plateau showing location of mapping projects.

Consolidated sedimentary rocks ranging from Pennsylvanian to Upper Cretaceous have an aggregate thickness in places of more than 15,000 feet. Pre-Cambrian crystalline rocks crop out in the northeast part of the area.

The major structural features in the area are the Uncompahgre Plateau uplift; salt intrusion anticlines that underlie Sinbad, Paradox, and Gypsum Valleys; Dolores anticline which probably has a salt core; Dolores-San Miguel syncline; Dry Creek Basin syncline; and Disappointment syncline. Minor structural features include numerous faults and small flexures along the flanks of the Uncompahgre Plateau uplift and the salt intrusions.

Uranium-vanadium ore deposits are confined largely to the Salt Wash member of the Morrison formation of Upper Jurassic age, but a few significant deposits have been found in the Brushy Basin member of the Morrison formation and in the saliferous Paradox member of the Pennsylvanian Hermosa formation. Most of these deposits are of the "carnotite" type, but at depth deposits containing unoxidized black uranium ore are being found.

Geologic guides believed to be generally of greatest usefulness are color and thickness of the sandstone strata, cross-bedded sandstone, organic matter, and the presence of altered gray-green mudstone in and underlying the ore-bearing sandstone. Most of the large deposits discovered thus far are within an arcuate belt, known as the Uravan mineral belt. This mineral belt extends through the length of the mapped area, and its trend appears to be unrelated to the regional geologic structures. However, in addition to the Uravan mineral belt there are concentrations of deposits along the flanks and axes of the salt anticlines that extend beyond the limits of the Uravan mineral belt as defined at the present time. Geologic mapping and

field studies indicate that these concentrations of deposits may be the result of one or both of the following geologic conditions:

1. The salt anticlines are zones of intense structural deformation and these zones may have served as channel-ways for ore-bearing solutions.
2. The ore-bearing Salt Wash member thickens abruptly in places along the salt anticlines which indicates some salt flowage was in progress during deposition of the Morrison formation. This salt flowage may have produced sedimentary structures favorable to the localization of ore.

With these factors in mind it appears reasonable that exploration along the trends of the salt anticlines west of the mapped areas may be warranted. Eastward the lithology of the known ore-bearing beds is unfavorable.

Compilation of geologic maps and preparation of accompanying texts for the eighteen $7\frac{1}{2}$ -minute quadrangles in southwestern Colorado has been completed. These will be published in the Geological Survey Quadrangle Map Series and in a preliminary form the maps will be transmitted to the AEC as TEM reports.

In addition, a paper on the structural development of salt anticlines on the Colorado Plateau and a comprehensive report on the geology of the eighteen $7\frac{1}{2}$ -minute quadrangles are in preparation. With the completion of these reports the Southwestern Colorado mapping project will be terminated.

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

Geologic mapping of the Carrizo Mountains area, Ariz. (fig. 1) was undertaken to provide detailed information on the geologic occurrence of carnotite deposits in the 30-minute quadrangle surrounding the Carrizo Mountains. Except for the laccolithic complex of the mountains the mapping

was completed in September 1951. At that time work was recessed to allow preparation of a preliminary appraisal of the uranium resources (TEM-300), preparation of the completed mapping for transmittal to AEC (TEM reports 415-430). Preparation of the geologic map, text, and stratigraphic sections has continued through the period, and this report will be transmitted for publication in the Oil and Gas Investigations Map series of the Geological Survey.

All known carnotite deposits in the Carrizo Mountains area are contained in the Salt Wash member of the Morrison formation. The position of the ore ranges from near the middle of the Salt Wash to the east and south of the mountains, down to the base of the Salt Wash northwest of the mountains. This may be a function of the thickness or composition of the Salt Wash, or it may be the result of some controlling factor superposed upon the Salt Wash, such as a former water table. If this surface of ore deposition should be related to the mountain uplift, fixing the time of uplift would provide geologic evidence for comparison with the radioactively determined age of the deposits. One of the best possibilities of dating the laccolithic intrusives of the Plateau is afforded in the Carrizo Mountains where sandstone of possible Cenozoic age caps the highest peak. Beyond this possible indirect relation of the uplift to the ore, evidence of a direct relation between igneous rocks and ore may be found, as carnotite deposits are known to occur close to some of the sills and laccoliths at the margins of the mountains. If the carnotite deposits should prove to have formed prior to the uplift, dating the uplift geologically would determine an upper limit to the time of ore deposition.

In fiscal year 1954 the 30-minute quadrangle will be completed by mapping the remaining 70 square miles in the Carrizo Mountains. Topographic maps will be available during the coming report period and will provide vertical control for analysis of geologic structure.

Monument Valley, Utah project, by D. E. Trimble and R. Q. Lewis, Sr.

Objectives of the Monument Valley strip mapping project, Utah are to appraise the uranium resources of the area, to determine geologic guides for prospecting, to locate areas favorable for exploration, and to map and study the uranium-bearing Shinarump conglomerate and adjacent strata to determine the regional controls and habits of uranium deposits.

The area is bounded on the north by the San Juan River and on the south by the Utah-Arizona state line. It is west of Monument Pass and east of Piute Mesa and lies within the area mapped by Baker (U. S. Geol. Survey Bull. 865). (See fig. 1.)

Sedimentary rocks, ranging from Permian to Jurassic (?) and having an aggregate thickness of more than 3,000 feet, crop out in the area. The only igneous rock is a small minette dike at the south edge of Oljeto Mesa.

The area is on the west flank of the Monument upwarp and subordinate asymmetrical folds are superposed on the major structure. Joints and faults are prominent in the rocks, especially in the sandstones.

The known uranium deposits are confined to rocks of Triassic age. Most deposits are in basal Shinarump sediments that fill channels cut into the Moenkopi formation. The channels are as much as 250 feet deep and 2,000 feet wide, but most channels are 30 to 50 feet deep and 200 to 400 feet wide. In some places, directly below channels, the bleached upper part of the Moenkopi is slightly mineralized. In April 1953 radioactivity ten times

greater than normal background was measured in Chinle mudstones. This measurement was general over a large area along the road to the Whirlwind mine on Monitor Mesa. Similar anomalies were noted in other areas of Chinle mudstone. The source of this abnormal radioactivity is unknown.

The only fault in the region that is known to cut the Shinarump is not radioactive. A zone of close jointing in the Cedar Mesa sandstone member of the Permian Cutler formation was also checked for abnormal radioactivity; no abnormal radioactivity was detected with a scintillometer.

Uranium minerals in the Monument Valley, Utah region occur as impregnations or coatings in the basal channel sediments. Carnotite, tyuyamunite, uranophane, torbernite, and autunite have been identified from the deposits and pitchblende has been reported from one locality, Mitten No. 1 mine.

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

The uranium minerals are in zones of relatively high permeability in the channel sediments of the Shinarump. These zones are marked by the presence of conglomerate, clay galls, friable sandstone, fractured clay lenses, or open-textured woody remains.

Any hypothesis of genesis of the uranium deposits in the Monument Valley area, Utah must account for several anomalous features of apparent age as determined from lead-uranium ratios, physical environment of the deposits, and mineralogy of the deposits. The youthful age of the deposits, as compared with the age of the host rock, and the accordance of age

determinations from many parts of the geologic column (Stieff and others, TEI-268, 1953) apparently requires that the ultimate source be magmatic hydrothermal solutions. The localization of the deposits within channel sediments suggests that ground water is the only possible agent of transport that could logically have resulted in such localization. The presence of uraninite, bornite, and chalcopyrite in the deposits indicates that the ground water had some properties of a magmatic solution. The uranium deposits, as they exist today, are primarily composed of secondary hydrated vanadates of uranium; probably the original deposits were leached and re-deposited as the secondary minerals, carnotite and tyuyamunite. The association of nodules of pitchblende in some of the mines in the region as well as the association of the bornite and chalcopyrite suggests that the redeposition was essentially in place. Too little is known at present of the source of the abnormal radioactivity in the Chinle mudstones to relate any deposits in the Chinle to those in the Shinarump.

During the month of January 1953, mining was begun at the Mitten No. 1 claim on Oljeto Mesa. This mine is in a remnant of the Skyline channel. Field examination of the surface outcrops at this locality made during the summer of 1952 gave no indication of the presence of an ore body. Wagon drilling, however, by the AEC during the summer of 1951 showed mineralized rock in several holes.

The presence of this ore body, which surface geologic examination did not disclose, suggests that any channel may contain an ore body. This concept necessitates a revision of the previous appraisal of the area and this region must now be considered potentially favorable for the discovery of new deposits.

Memoranda are in preparation recommending physical exploration of the channel containing the newly discovered mineralized locality on the mesa northwest of the Oljeto Trading Post reported in TEM-353 (Trimble, 1952), the Whirlwind channel, and other favorable areas in Monument Valley, Utah. TEM-321, the final report covering the results of the investigation will be transmitted to the AEC during the next report period. This report will also be prepared for publication as a Geological Survey Circular. Transmittal of the above reports will complete this project.

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

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

Geologic mapping and field studies were undertaken during the field seasons of 1951 and 1952. An area of about 700 square miles on the Navajo Indian Reservation was mapped.

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

The major structural feature in the area is the Monument upwarp, a broad flattened anticline with a north-south axis. On this major feature four smaller asymmetrical folds are superimposed.

Uranium-vanadium ore occurs in Shinarump conglomerate that fills symmetric and asymmetric troughs scoured as much as 75 feet into the underlying

Moenkopi formation. These troughs or channels range from 15 to about 2,350 feet wide and up to 4 miles long. The major ore bodies are erratically distributed along the length of a channel. Fifty-eight channels have been noted in the area; seventeen channels contain exposures of mineralized rock.

Most ore deposits are of the "carnotite" type. The predominant ore mineral is either carnotite (?), tyuyamunite (?), or locally an unnamed vanadate. Uraninite, becquerelite, and uranophane also occur. Many ore deposits have copper minerals, such as azurite, malachite, chalcocite, and chalcopyrite, intimately associated with the uranium minerals.

The major uranium deposits in the Vanadium Corporation of America's Monument No. 2 mine appear as "rolls", flattened cylindrical bodies that average about 3 to 5 feet wide, 2 to 3 feet high, and 15 to 20 feet long. The vanadium deposits form irregular masses that impregnate basal channel sediments and in places the underlying sediments. Not all of the channel sediments filling the Monument No. 2 channel are mineralized; barren areas alternate at irregular intervals laterally and vertically with richly mineralized zones.

The geologic features believed to be of greatest usefulness as guides in the search for new ore deposits in the Monument Valley area are channels, observable uranium minerals and abnormal radioactivity, fossil plant matter, conglomerate containing fossil plant matter. Geologic features of uncertain value are limonite impregnation, copper minerals, thickening of a bleached zone at the top of the Moenkopi formation, and clay boulders, cobbles and pebbles.

Field work on the project is essentially completed. Plans for the next six months period include: (1) field checking of maps and sampling in

connection with preparation of a summary of ore reserves, (2) preparation of a final report for transmittal to the AEC and as a U. S. Geological Survey Bulletin. When these reports are transmitted the Monument Valley, Ariz. project will be terminated.

Red House Cliffs project, by T. E. Mullens

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

The Red House Cliffs area (fig. 1) is in the southwestern San Juan County, Utah. The area includes five $7\frac{1}{2}$ -minute quadrangles in the Clay Hills 30-minute quadrangle. Four of these quadrangles include the area of Triassic rock exposures on the western flank of the Monument upwarp between the head of Red Canyon and the San Juan River. The fifth quadrangle is included in the project in order to complete the structural pattern of the area.

Field work in the Red House Cliffs area started in July 1952 and continued until October 1952. During the 1952 field season the Chinle-Moenkopi contact in three $7\frac{1}{2}$ -minute quadrangles, about 20 miles of outcrop, was studied in detail and examined for uranium minerals and geologic mapping of the three quadrangles was about 90 percent completed. A preliminary report transmitted in November 1952, TEM-537, by T. E. Mullens and H. A. Hubbard, summarized the results of 1952 field studies.

Field work was resumed in early May 1953 and one $7\frac{1}{2}$ -minute quadrangle has been mapped this year.

No known deposit of uranium minerals occurs in the part of the Red House Cliffs area mapped to date. Malachite, a copper carbonate, is

disseminated in a small lens of Shinarump conglomerate, but no radioactive material is associated with the malachite.

Geologic mapping and studies in the Red House Cliffs area have resulted in positive correlation of a cliff-forming unit at the top of the Cutler formation with the Hoskinnini tongue of the Cutler formation. Geologic mapping has revealed two fault zones which may be related to localization of uranium ore in Red Canyon north of the Red House Cliffs area. These two fault zones extend beyond the north boundary of the Red House Cliffs area and into Red Canyon where they crop out near some of the uranium mines. No uranium minerals are associated with the fault zones in the Red House Cliffs area, and more field work is needed to prove or disprove any relation between these faults and the uranium deposits in Red Canyon.

The probability of finding uranium ore in the part of the Red House Cliffs area mapped to date is low because there are few beds favorable for these deposits along the outcrop. Only five lenses of Shinarump conglomerate, the formation in which uranium commonly occurs in this region, crop out in the area mapped. The largest lens of Shinarump extends only about 2 miles along outcrop and has a maximum thickness of 20 feet; the other four lenses extend less than a quarter of a mile along outcrop and are less than 8 feet thick. Ore-bearing Shinarump in Red Canyon, in White Canyon, and in areas south of the San Juan River is more persistent and thicker than the Shinarump exposed in the mapped part of the Red House Cliffs area.

Similarly the $7\frac{1}{2}$ -minute quadrangle Clay Hills 2 NW is probably underlain by relatively thick and persistent Shinarump conglomerate which may be favorable for ore deposits. However, the Shinarump in this quadrangle is buried by about 1,200 feet of younger sediments and cannot be examined.

In addition to the Shinarump conglomerate, the other formations exposed in the area were examined for uranium. No uranium minerals were noted in these formations, and the probability of finding uranium ore deposits in these formations is thought to be low.

Plans for the Red House Cliffs project are: (1) to complete mapping and geologic studies in the area during the summer of 1953 and (2) to complete a final report on the project for transmittal to the AEC early in 1954.

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

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

The White Canyon area is on the west flank of the Monument upwarp in the central part of San Juan County, Utah, about 50 miles west of Blanding, Utah. (See figure 1.)

Work during the last six months has included the preparation of TEI-240, "Uranium and copper deposits at the North Point claim, White Canyon area, San Juan County, Utah," by A. F. Trites, Jr., E. P. Beroni, and J. A. Feeger and TEM-645, "Preliminary report on Happy Jack mine, San Juan County, Utah," by A. F. Trites and R. T. Chew. Diamond drilling data made available by the Grand Junction Exploration Branch of the AEC has been compiled. Structural and channel data in the White Canyon area has also been compiled.

Field work was resumed in April 1953 and about 40 square miles in the lower White Canyon area have been mapped this year. Detailed geologic mapping has been continued at the White Canyon No. 1 claim. Geologic investigations have begun at the Jomac claim. Diamond drilling was recommended in the Deer Flats area, and geophysical work was recommended in the Happy Jack, Frey Point, Deer Flats, and Posey areas.

Geologic studies in the White Canyon area indicate that most of the uranium deposits are in the Shinarump conglomerate. Three types of deposits are recognized on the basis of the grain size of the enclosing Shinarump beds: (1) relatively continuous high-grade ore bodies found in coarse sandstone, (2) ore bodies composed of high-grade areas separated by low-grade areas found in channel-fill conglomerate, and (3) sparse but relatively continuous low-grade deposits found in siltstone or very fine-grained sandstone.

Many of the deposits are on the flanks or near the bottom of channels cut in beds of the Moenkopi formation and filled by Shinarump sediments. At least 18 channels have been found by geological mapping and by diamond drilling by the Grand Junction Exploration Branch of the AEC. These channels range from less than 150 feet wide and 7 feet deep to more than 500 feet wide and 30 feet deep. No correlation has been established between the size or shape of the channels and the amount or grade of uranium bodies, although a broad shallow channel appears to have been the site for uranium deposition at the Happy Jack and Posey mines, the principal uranium deposits in the area.

Uranium minerals in the White Canyon area include pitchblende or uraninite, and secondary sulfates, phosphates, and carbonates. These minerals occur (1) in clay stringers, (2) at lithologic contacts, (3) as

replacements of wood, and (4) as impregnations in sandstone and conglomerate. The pitchblende or uraninite is associated most commonly with covellite, although it has been found with bornite and chalcopyrite.

Geochemical studies at the North Point claim suggest that ground-water solutions have removed uranium, copper, manganese, iron, calcium, lead, zinc, molybdenum, cobalt, and nickel from the ore body and deposited them along fractures and in the rocks adjoining the fractures.

Geologic investigations planned for the 1953 field season include geologic mapping of a large part of the White Canyon area; detailed examination of the Shinarump conglomerate in the area; preparation of structural contour map; an areal study of the fault and joint pattern; detailed examination of uranium deposits; and stratigraphic studies. TEM-540, "Preliminary report on geologic investigations in White Canyon, San Juan County, Utah, 1952," by A. F. Trites, Jr., and T. L. Finnell has been transmitted to the AEC. This report briefly summarizes results of field work in 1952. Manuscripts are now being processed to be transmitted to the AEC this summer. After the end of the 1953 field season a detailed interim report will be prepared.

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

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

The area in which mapping has been completed is in western Wayne County, Utah. The complete area to be mapped includes also a part of northern Garfield County. (See fig. 1.)

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

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

Beta-zircone, metatorbernite, johannite, and specks of pitchblende disseminated in carbonaceous material from the Oyler mine have been identified by the Geological Survey Trace Elements Laboratory in Washington. Metatorbernite has been found at the Birch Spring and Floral Reef claims. Secondary copper minerals, minute grains of chalcopyrite and pyrite, gypsum, and in places iron and manganese stain are associated with the uranium minerals.

Radioactive asphaltite forms coatings on and blebs in red chert in the Shinarump in sec. 36, T. 29 S., R. 26 E. Stringers of red chert at the Moenkopi-Chinle contact just south of Pleasant Creek are slightly radioactive.

The habits of uranium occurrence in the Capitol Reef area indicate that the following geologic features may be useful as guides for prospecting, particularly where several are found together: (1) Shinarump sediments in channels cut into the underlying Moenkopi formation, (2) copper minerals, (3) fractures heavily stained with iron and manganese, (4) concentration of carbonaceous matter, (5) clay layer at base of Shinarump conglomerate, and (6) thick zone of bleached clay and siltstone at the top of the Moenkopi formation.

Areas favorable for uranium deposits are limited to the Shinarump conglomerate. At present, no parts of the area studied are considered favorable for drilling exploration.

TEM-538, "Preliminary report on geologic studies in the Capitol Reef area, Wayne County, Utah, 1952" was transmitted to the AEC during this reporting period.

Geologic mapping and field studies were resumed in May and will be continued probably until October. An interim report will be prepared during this winter, 1953-1954, for transmittal to the AEC.

As an additional study, L. C. Huff is investigating chemically the lower part of the Chinle formation to find out whether a genetic relation exists between bleaching in the Chinle and uranium mineralization in the Shinarump. Preliminary results suggest that the bleaching at the base of the Chinle was accomplished by acid, reducing solutions which deposited zinc and copper but no uranium in the bleached zone. As a working hypothesis he suggests that the bleaching solution was the same one which deposited uranium in the Shinarump. This study will be continued and a TEM report on the preliminary results is being prepared.

Photogeologic mapping
by William A. Fischer

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

Since the beginning of the photogeology project in the winter of 1951-1952, approximately 9,500 square miles of geologic mapping has been completed or is in the latter stages of production. These areas completed or in active production are shown on figure 2.

As a result of conferences held with representatives of the Grand Junction Office of the U. S. Geological Survey, the amount of detail presented on the photogeology maps is being increased.

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

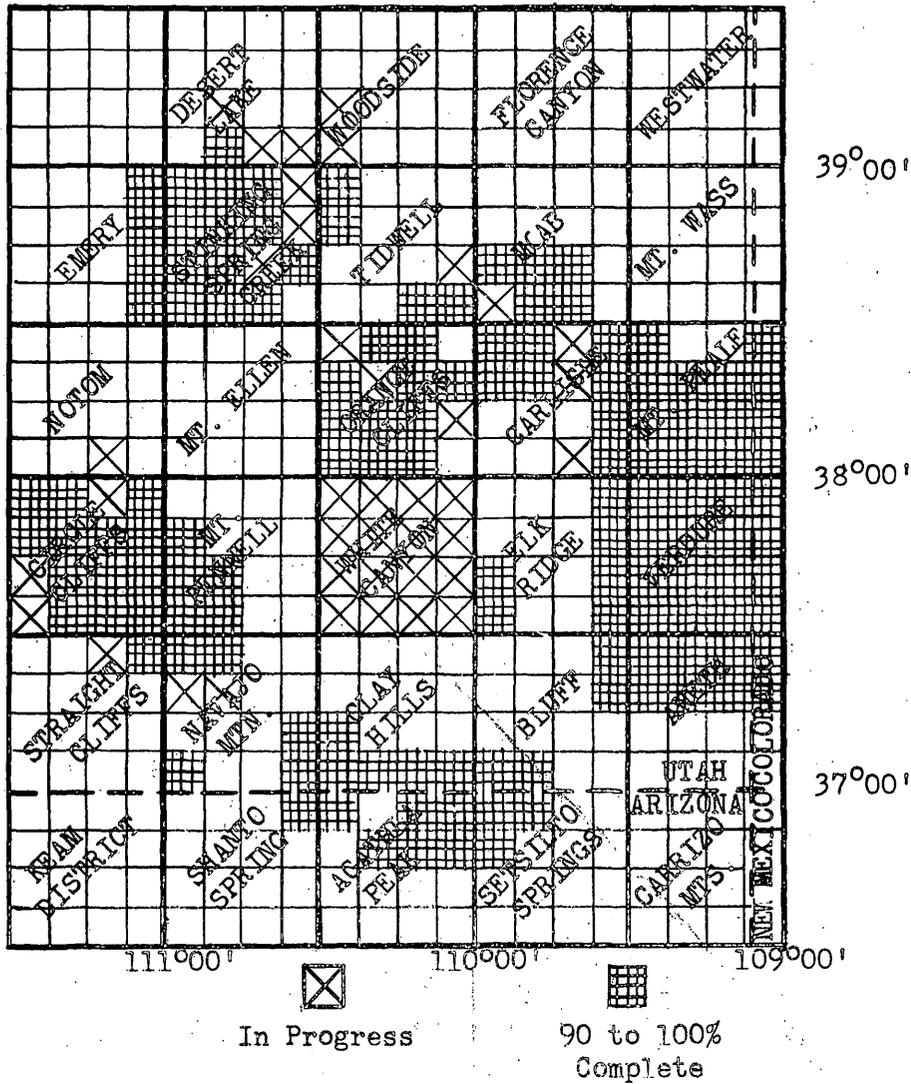
Stratigraphic studies
by G. A. Williams

Morrison formation

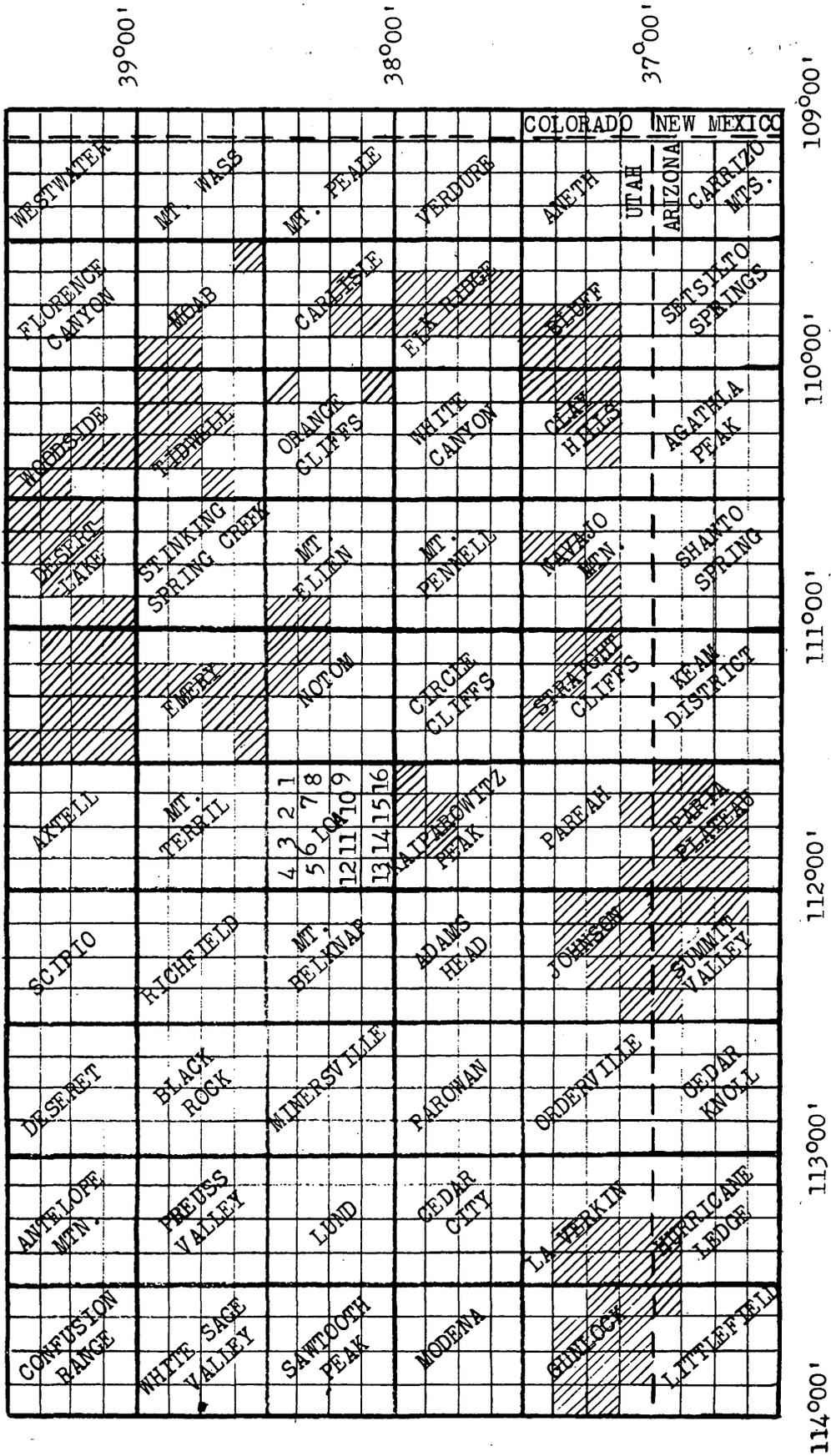
The objectives of the stratigraphic studies of the Morrison formation of the Colorado Plateau region are to provide information regarding distribution variations in lithology, source and character of constituting materials, conditions of deposition, and post-depositional history of the ore-bearing Morrison formation and associated formations. Preliminary results of these studies have been summarized in TEI-180, "Preliminary report on the stratigraphy of the Morrison and related formations of the Colorado Plateau region," November 1951. This report will be made available to the general public as a U. S. Geological Survey Bulletin.

FIGURE 2

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



INDEX MAP
 Showing scheduled photogeologic mapping for fiscal 1954-55



30' quadrangles subdivided into 16 7½ quadrangles (see Loa quadrangle)

FIGURE 3

The Morrison study was recessed July 1, 1952 until May 30, 1953 except for special studies conducted by the sedimentology laboratory. Preparation of reports on sedimentary structures, sedimentary petrology, and pebble studies are in progress for inclusion in a final report on the Morrison formation. TEM-627, "Lithofacies of the Salt Wash member of the Morrison formation," by T. E. Mullens and V. L. Freeman is near completion; this report is planned for publication in a professional journal.

Pebbles in the Salt Wash member of the Morrison show a general decrease in size from southwestern Utah to western Colorado. Among the pebbles are distinctive lithologic types containing fossils that suggest the Kaibab limestone as a source for at least some of the material comprising the Salt Wash member.

Most of the petrologic evidence to be used in the final report on the investigation of the Morrison formation has been assembled. The only work uncompleted is the study of thin sections of representative sandstones.

Based on the regional petrology, the Morrison formation in the Colorado Plateau area probably had three general source areas. The source areas as identified from their derived sediments were: (1) a granitic igneous terrane with minor volcanics and sediments possibly in central New Mexico; (2) a sedimentary terrane west and southwest of south-central Utah; and (3) a granitic igneous terrane and a major source of volcanic material from west or northwest of central Utah.

Not all of the four recognized members of the Morrison received contributions from all of the sources except possibly in minor amounts. The Salt Wash and the Brushy Basin members in their northern extensions, north of the Arizona-Utah, and New Mexico-Colorado borders, represent the mixing

of sediments which were brought in by streams from the three source areas. The Recapture and the Westwater members were derived from the granitic terrane to the southeast and from previously deposited sediments to the south. The Westwater, however, is much more feldspathic and contains less sedimentary and more volcanic material than the Recapture member. The Brushy Basin contains much more volcanic material than the Salt Wash; the major source of which may have been the source area to the west or northwest of central Utah.

The uranium deposits of the Salt Wash member in the Uraavan mineral belt lie within an area which has received a significantly larger than average amount of potassium feldspar and volcanic debris from the western source during the deposition of the Salt Wash member. The volcanic material identified includes rhyolitic tuff, fragments of rhyolite, and the heavy mineral apatite; these components were supplied intermittently and the superimposed strata contain varying amounts of volcanic material that ranges from 1 to 15 percent of the sedimentary rocks. The possible relation of the uranium ore deposits to the tuff-bearing sandstones has been discussed by Waters and Granger (U.S.G.S. Circ. 224, 1952), who emphasized the need for quantitative data on the distribution of volcanic material in the ore-bearing formations.

Plans for the Morrison studies during the next six months call for some field checks, the completion of the laboratory studies including a study of the relation of the distribution of volcanic debris to uranium deposits, and the continued preparation of a comprehensive final report.

Triassic formations

Stratigraphic studies of the Triassic and associated formations in the Colorado Plateau region are planned to obtain information regarding the

areal distribution, local and regional differences in lithology, sources and character of constituting material, and conditions of deposition of the ore-bearing Shinarump conglomerate and associated formations.

Field work was essentially completed in the Monument Valley area in 1951 and in the Circle Cliffs, Garfield County, Utah; Capitol Reef, Garfield and Wayne Counties, Utah; White Canyon, and Red House Cliff areas, San Juan County, Utah, in 1952. Preliminary work has been started in the Kanab area, Kane and Washington Counties, Utah. The compilation of data collected in these areas is largely complete except for laboratory studies.

Noteworthy results of the work during this period are summarized. The Permian Coconino sandstone is inferred to intertongue and intergrade to the east from the Capitol Reef and Circle Cliffs areas into reddish siltstone composing the Halgaito and Organ Rock tongues of the Cutler formation in southeastern Utah. The White Rim, Cedar Mesa, and DeChelly sandstone members of the Cutler probably are tongues of the Coconino. The Coconino sandstone and the sandstone members of the Cutler are interpreted as mainly eolian deposits whereas the Halgaito and Organ Rock tongues are probably subareal or marginal marine deposits.

The Kaibab limestone may grade to the east of the Capitol Reef and Circle Cliffs areas into sandstones that may correlate with the White Rim sandstone member of the Cutler. The Kaibab is well known as a marine deposit but in the Capitol Reef and Circle Cliffs areas it appears to contain marginal marine beds.

The Hoskinnini tongue, although included in the Cutler formation of southeastern Utah, shows several features that separate it from the rest of the Cutler. The Hoskinnini has been traced northward from Monument Valley to the middle of the White Canyon area where it abruptly pinches out. The

Hoskinnini may be a marginal marine deposit. Near the pinchout it contains a basal chert conglomerate which closely resembles a basal chert conglomerate in the Moenkopi and which was possibly derived from the Kaibab. Thus, the Hoskinnini may be a post-Kaibab unit and may be actually of Triassic age.

The Triassic Moenkopi formation thins eastward from the Kanab and Capitol Reef areas of south-central Utah. The Sinbad limestone member of the Moenkopi and the underlying Moenkopi siltstone thin southward from the Capitol Reef area; in the northern Circle Cliffs the Sinbad lies at the base of the Moenkopi; and in central Circle Cliffs it pinches out. The Moenkopi is dominantly siltstone or very fine-grained sandstone and is probably a marginal marine deposit that was formed in a sea that transgressed from the west to the east across Utah.

The Upper Triassic Shinarump conglomerate in the areas studied shows regional variations in thickness and in the depth and width of the channels at its base. The sandstones of the Shinarump are fine- to coarse-grained arkoses. The pebbles in the Shinarump show regional variations in composition, roundness, sphericity, and size that indicate a multiple source. The cross-strata in the Shinarump dip dominantly to the north or northwest. The Shinarump is probably a stream deposit that derived its sediments, at least in part, from source areas in southern Arizona and New Mexico.

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

The Jurassic (?) Glen Canyon group which consists of the Wingate sandstone, Kayenta formation, and Navajo sandstone is composed of a thick sequence of interrelated rocks. The Wingate lies with a sharp lithologic break on the Chinle and locally it lies unconformably on the Chinle. The Wingate and Navajo are predominantly eolian deposits whereas the Kayenta is probably a stream deposit.

The uranium deposits in southern Utah and northern Arizona occur dominantly in the Shinarump conglomerate. However, significant deposits occur in the Permian Cutler formation and the Triassic Chinle formation.

The ore deposits in the Shinarump conglomerate seem to be concentrated in areas where the Shinarump changes from a continuous to a discontinuous unit. No significant ore deposits are known in the continuous Shinarump of the westernmost part of Monument Valley, the southern Circle Cliffs, or the Kanab areas. However, ore deposits are present in the marginal belt where the continuous Shinarump changes to a discontinuous unit, as in eastern Monument Valley, White Canyon, and northern Circle Cliffs. No ore is known in the Red House Cliffs area where the Shinarump is almost entirely absent.

The Chinle formation in various areas contains beds similar in texture and general character to the Shinarump conglomerate. The recent discovery of ore deposits in the Chinle as well as the recognition of greater than background radioactivity at several places in the Chinle supports the need for continued study of possible uranium host rocks in the formation. Similarly, some uranium has been produced from the Cutler formation of east-central Utah and study of possible host rocks is warranted.

During the next report period, the stratigraphic studies group will extend the field work into central and east-central Utah. Several areas

essentially completed will be revisited to collect additional data and train new personnel. A special study of the Shinarump conglomerate aimed at a better understanding of the distribution and the lenticularity in relation to the ore-bearing parts of the Shinarump will be initiated. A more detailed study of the distribution and character of the volcanic debris and its relation to the ore-bearing rocks of Triassic formations will be started by the sedimentary petrology laboratory.

Ground-water studies
by D. A. Jobin

Ground-water studies were begun in 1950 to determine present and past ground-water conditions in the ore-bearing rocks of the Morrison formation and the influence these waters may have had on the genesis and localization of the ore deposits. Results of this study are summarized in TEI-161, "Present and past ground-water conditions in the Morrison formation in southwestern Colorado and southeastern Utah," by D. A. Phoenix, December 1952.

In March 1953, work began on the problem of determining the horizontal and vertical ~~transmissibility~~ relationships of the exposed sedimentary formations on the Colorado Plateau. This study will provide some basic information which will be used together with the stratigraphic and structural histories of each depositional district to delineate the probable "plumbing systems" during the Mesozoic and Cenozoic. In turn these analyses may be used to point out other areas of similar hydrologic and geologic histories whose ore-bearing potentialities should be explored.

During this report period most of the effort has been spent in working out methods of procedure. In this connection the Survey ground-water

laboratory at Lincoln, Neb. and Bureau of Mines petroleum technology laboratory in San Francisco, Calif. were visited and their equipment and procedures studied. Information, advice and criticism were also obtained from the Ground-water offices at Salt Lake, Denver, and Holbrook. Arrangements for the exchange of pertinent information were made during these visits.

Plans for the study have been formulated. The exposed sedimentary rocks will be sampled initially in six areas: Uravan-Gateway, Colo.; Monument Valley, Utah-Ariz.; West San Juan Mountains, Colo.; San Rafael Swell, Utah; Circle Cliffs-Straight Cliffs, Utah; and an area near the junction of the Colorado and Green Rivers, Utah. After the permeability is determined, each sample will be disaggregated and measurements will be made of grain size distribution and amount and kind of matrix. Thin sections and specially impregnated polished sections will be made from sub-samples to determine the paragenesis, form and distribution of cementing materials, composition of the rocks and geometry of the pores. An attempt will be made to relate the permeability values to other measured parameters so that the large accumulation of sedimentologic data available from the stratigraphic studies group can be utilized for obtaining indirect permeability measurements. Drilling data will be used to supplement theoretical calculations on the effect of fractures on permeability.

The plans for the regional transmissibility project for the next period include completing the initial sampling of the six regional sites and completion of a large amount of the laboratory work on these samples.

Geobotanical studies

Geobotanical research, by H. L. Cannon

Geobotanical prospecting research is planned to investigate the use of indicator and absorber plants in prospecting for shallow uranium ore bodies. Objectives of work during the past reporting period have been two-fold: (1) to appraise the use of geobotanical prospecting methods in selected uranium districts, and (2) to further study the application of geobotanical prospecting methods in areas of different climatic and geologic environmental conditions, both on and away from the Colorado Plateau.

Short reconnaissance studies were made on uraniumiferous-phosphate deposits near Plant City, Florida; on deposits along the Lisbon Valley, Paradox Valley, and Gypsum Valley salt anticlines; and in uranium-producing areas in the Green River and Henry Mountains districts in Utah.

In the phosphate fields of Florida the uranium is concentrated in the aluminum phosphate fraction of the "leached" zone in the Bone Valley formation of Pliocene age. These beds are flat-lying with an overburden of about 10 feet of sandy soil. Forty samples of pine, oak, and palmetto were collected from mineralized and barren areas and along a traverse previously tested by drilling. It is hoped that the near-surface, stagnant ground water will not disturb the absorption of uranium by the vegetation. Chemical assays have not yet been received.

Of the Plateau areas visited, Paradox Valley and Circle Cliffs are recommended as most promising for further geobotanical work. Plant distribution on parts of Carpenter Ridge on the northeast side of Paradox Valley is identical to that of the Jo Dandy group of mines on the southwest side of the valley. Certain indicator plants may be used at both localities

to indicate mineralized ground and also to determine major fracture systems possibly related to the location of ore trends. Mapping of key indicator plants on a portion of Carpenter Ridge and in the Jo Dandy group is planned for the next report period in advance of drilling.

Small ore bodies have been found in the Triassic Shinarump conglomerate of the Circle Cliffs area of Utah. The area is favorable for geobotanical prospecting by the absorber and indicator plant methods. The Shinarump forms extensive tree-covered benches which are ideal for systematic sampling of absorber trees. Indicator plants appear to be present consistently along mineralized portions of the outcrop and can be used in delineating favorable portions of the Shinarump bench. Indicator plants also delineate major concentrations of selenium in petroliferous portions of the underlying Moenkopi formation which may have a significant bearing on the origin and distribution of the uranium deposits. The extent of this association can be investigated by studying the distribution of Astragalus pattersonii throughout the valley. A major geobotanical prospecting project is recommended in this area for the summer of 1954.

TEM-579, "Interim report on geobotanical results in the Yellow Cat area, Thompson district, Grand County, Utah," by H. L. Cannon will be transmitted during the next reporting period. A report on "Geobotanical reconnaissance near Grants, New Mexico," by H. L. Cannon was released during this report period as U. S. Geological Survey Circular 264. TEM-575, "Geobotanical reconnaissance at La Ventana Mesa, Sandoval County, New Mexico," by H. L. Cannon was transmitted to the AEC during this report period and a short report giving the results of geobotanical reconnaissance in the Craven Canyon area, Fall River County, South Dakota is in preparation. Further

work is planned in the Craven Canyon area and a program of sampling recommended at La Ventana Mesa was completed this spring. On La Ventana Mesa the absorption of uranium by trees rooted in a 65 foot sandstone is sufficient to outline anomalous areas behind the rim as favorable for drilling.

Research is continuing on the relation of plants to the geochemistry of uranium deposits. As a corollary of this study, an experimental garden has been established in Santa Fe, N. Mex., to study absorption phenomena under natural conditions. Sixteen key species of indicator plants have been planted in 16 plots which have been enriched with combinations of uranium, vanadium, selenium, phosphorus, calcium, and sulphur.

A handbook of indicator plants originally scheduled to be released this spring has been postponed due to insufficient illustrative material. Additional photographs and drawings are being obtained.

Studies will be made of the plant relations at Guadalupita, N. Mex., and on vein deposits on the Front Range. Reports on comparative studies of plant relations on the phosphate deposits of Idaho and Wyoming and also those in Florida will be prepared during the late summer.

Geobotanical prospecting, by P. F. Narten

Objectives of geobotanical prospecting projects on the Colorado Plateau are to delineate by geobotanical methods areas favorable for physical exploration for hidden ore deposits. During the current reporting period, the analysis of absorber plants has been used as a method of prospecting in an area near Grants, McKinley and Valencia Counties, N. Mex., and in Deer Flats, San Juan County, Utah. Reconnaissance prospecting by a study of indicator plant distribution will be used as a supplementary guide to mineralized areas in the San Rafael Swell, Emery County, Utah.

Geobotanical prospecting by the absorber plant method was tested and the indicator plant method evaluated in the Grants district, McKinley and Valencia Counties, N. Mex. between June and November 1952. Most of this work was done upon the broad forested dip-slope bench formed by the Jurassic Todilto limestone and resulted in the collection and analysis of about 3,500 branch and peeled-branch samples of pinyon (Pinus cembroides) and one-seed juniper (Juniperus monosperma) over about 9 square miles of the Todilto bench from sec. 4, T. 11 N., R. 9 W. in Valencia County northwestward through sec. 17, T. 14 N., R. 12 W. in McKinley County. Analyses of one ppm (part per million) uranium and above in the ashed sample were used arbitrarily as an indication of mineralized ground (an anomaly).

Isopleth maps, completed for all areas east of T. 14 N., R. 12 W. by section or groups of sections, show anomalies in almost every section sampled. Preliminary copies of these maps have been sent to the AEC District Geologist at Grants, N. Mex.

Because the systematic sampling on the Todilto bench included areas which were being physically explored by private enterprise, comparative data for evaluation of geobotanical prospecting by the absorber plant method was accumulated. Study of available data shows that geobotanical anomalies correlated well with known mineralized areas. The anomalies have proven useful in extending some of the areas. Some geobotanical anomalies were also found in the physically prospected areas where ore had not been reported. These favorable anomalies are not fully understood but may represent only weakly mineralized ground below commercial grade. It appears that no direct relationship exists between the amount of uranium in a tree sample and the total amount of uranium present in the ground and each geobotanical anomaly.

must therefore be tested for its own worth. Evaluation of anomalies found in unprospected areas and selection of areas for exploration may be based on the size of the anomalies; their relationship to the grade of adjacent known deposits; and their location. Many large anomalies occur in areas of thick colluvial cover beyond the topographic expression of the Todilto dip-slope and cannot be evaluated until tested by exploration.

A few samples were taken to test the absorber plant method in several small areas on the benches formed by the Cretaceous Dakota sandstone. The results of this study are encouraging and the Dakota is probably as amenable to this method of geobotanical prospecting as the Todilto. A short report of these results was sent to the AEC District Geologist in March.

Indicator plant studies have shown that the indicator plant method of prospecting is not suitable on the benches formed by the Todilto limestone and the Dakota sandstone in the Grants area. Detailed mapping of indicator plants on the Jurassic Morrison formation has shown, however, that a species of Astragalus which is a selenium indicator may be useful in delimiting favorable areas in the sandstone members of the Morrison.

TEM-580, "Preliminary report on geobotanical prospecting, Valencia and McKinley Counties, New Mexico," by P. F. Narten and W. H. Starrett is being prepared for transmittal to the AEC. A final report with an appraisal of the usefulness of the geobotanical methods of prospecting in the Grants district must await drilling on the anomalies already discovered.

Detailed sampling of juniper branch tips from trees slightly above the top of the Shinarump conglomerate was begun on May 8, 1953 at Deer Flats, San Juan County, Utah. Samples have been taken at 200-foot intervals where the Shinarump conglomerate is well exposed, but where it is covered by slump or talus, samples have been taken at 50-foot intervals. Traverses with

samples spaced at a vertical interval of from 10 to 60 feet have been made from the top of the Moenkopi formation to the top of the Chinle "D" member at intervals of about one mile. About six and one-half miles of outcrop have been sampled. The analyses of the tree samples for uranium have not been completed. Prospecting of a similar nature is planned along the remaining 10 miles of Shinarump conglomerate on Deer Flats and will be eventually extended to the Elk Ridge area, Utah.

A project of indicator plant mapping in the San Rafael Swell, Emery County, Utah, will be started on June 20, 1953, and continue until fall. It is planned to study indicator plant distribution near known uranium deposits in the Shinarump conglomerate and to extend the study by reconnaissance throughout various geologically favorable areas of the Swell. Similar plant associations will be mapped for further geologic investigation.

Resource appraisal

The aim of the resource appraisal program is to synthesize available data on the distribution of uranium deposits in the Colorado Plateau province in order to determine systematic geologic relationships that may help guide exploration for ore and aid in evaluating the total resources of the province. In fiscal 1953 reconnaissance studies of the deposits in pre-Morrison rocks were continued and compilation of available information on the distribution of Morrison deposits in the Uravan mineral belt was begun.

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

Compilation of maps showing known deposits and favorable ground in the Salt Wash member of the Morrison formation was begun. Maps covering the Uravan, Gateway, and Paradox districts have been prepared and will be

available for examination at the Geological Survey Grand Junction office. The distribution pattern will be analyzed to determine regional trends of ore concentration, and to relate it to such factors as lithologic units, structures, erosion surfaces, and inferred ground water surfaces. The study will be extended to the remaining parts of the Uravan mineral belt and then to other areas containing known deposits on the Colorado Plateau. Progress reports will be prepared covering unit areas of sufficient size to yield significant appraisals and relationships.

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

The regional distribution of uranium and vanadium as indicated by drill-hole assays will supplement the ore distribution study. Drill-hole samples can be considered random samples and are amenable to statistical and geologic analyses. Analyses of the regional variations in grade and the relative amounts of uranium and vanadium will yield patterns that may be related to geologic or mineralogic factors. Stratigraphic variations in grade and metal ratios will be studied, and comparisons will be made between deep-seated and near-surface deposits. This study is planned to begin late in fiscal year 1953 or early fiscal year 1954.

Pre-Morrison resource appraisal, by W. I. Finch

The objectives of the pre-Morrison appraisal are to obtain an evaluation of the deposits in the pre-Morrison formations, particularly the Shinarump conglomerate, to determine the geologic habits of uranium in pre-Morrison rocks, to compare Morrison and pre-Morrison deposits in the Colorado Plateau, and to determine areas favorable for exploration or specialized geologic studies.

During this reporting period reconnaissance studies were made in the Cameron-Holbrook, Ariz. and Big Indian Wash area, Utah. Progress of the work to date has been summarized in TEM-574, "Interim report on the resource appraisal of uranium deposits in pre-Morrison formations of the Colorado Plateau," by W. I. Finch. Three belts of ground favorable for better than average deposits are outlined. One belt is formed by the alignment of significant deposits and geologically favorable ground from Temple Mountain and the southern part of the San Rafael district, Utah, through the central part of the Green River district to the Big Indian Wash area, Utah. The second belt is in the White Canyon district, Utah, and the third in Monument Valley, Utah and Arizona. Analyses of data obtained from detailed mine mapping has begun. Results of the mine studies will be reported in TEI-287, "Geology of the Shinarump No. 1 mine, Grand County, Utah, with a general account of uranium deposits in Triassic rocks of the Colorado Plateau," by W. I. Finch.

Field work will be resumed during the field season of 1953 and will include further reconnaissance studies and detailed mine-mapping to check and refine concepts developed during the last field season. A more detailed and comprehensive report on pre-Morrison uranium deposits will be prepared at the end of the 1953 field season.

A study of the radioactivity of present stream gravels was undertaken by R. T. Chew as part of the pre-Morrison resource study. Preliminary results indicate that anomalously high radioactivity in modern stream gravels is a useful prospecting aid under certain restricted conditions, and that deposits can be detected, in some cases, as much as one mile downstream. TEM-629, "Preliminary report on the study of radioactivity in modern stream gravels," by R. T. Chew, III summarizing results of this study to date is

in preparation. Plans include additional field work in selected areas and preparation of a final report on this method of prospecting.

Cenozoic studies

The Cenozoic studies are aimed at providing a systematic understanding of the Cenozoic history of the Colorado Plateau and the influences it may have had on the origin or history of the sandstone-type uranium deposits.

During 1952, the stratigraphy and structure of Cenozoic formations in various parts of the Colorado Plateau were studied. A preliminary report synthesizing existing knowledge of the Cenozoic is in preparation.

Evidence collected for this study suggests that the laccolithic intrusions are Middle Miocene and therefore, are much younger than the bedded uranium deposits of the Colorado Plateau which are dated as late Cretaceous or Eocene by lead-uranium ratios.

During the next report period the preparation of the summary report will be continued and some field investigations of selected areas and special problems may be undertaken.

Mineralogic studies

General mineralogic studies, by A. D. Weeks and L. B. Riley

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

Localities on the Colorado Plateau in which uraninite (pitchblende) has been found and identified now total 23. These occurrences are about equally

divided between vanadiferous and non-vanadiferous uranium ores.

The "zippeite" from the Plateau still is a mineralogical problem. Although a chemical analysis of material from Capitol Reef, Utah, is similar to that of zippeite from Europe, the X-ray patterns differ. In the semi-annual report, TEI-310, it was suggested that the Plateau "zippeite" might be monoclinic, based on optical studies, but preliminary single crystal X-ray study by H. T. Evans indicates that it is orthorhombic.

Two new minerals have been studied and their descriptions are now being written by M. E. Thompson and A. D. Weeks. Both have been analyzed chemically by A. M. Sherwood. One, probably $V_2O_5 \cdot 3H_2O$, occurs abundantly in the South Rim workings of the Monument No. 2 mine, Monument Valley district, Ariz. A new uranium carbonate, tentatively called rabbittite [probably $Ca_3Mg_3(UO_2)_2(CO_3)_6(OH)_4 \cdot 18H_2O$] was found in the Lucky Strike No. 2 mine, San Rafael district, Utah. H. T. Evans has determined one lattice constant of each of these minerals, which seem too fine-grained for further single crystal X-ray study.

Samples of four minerals now awaiting chemical analyses, after separation and purification, are tentatively identified as cobalt uranyl sulphate (?), sodium hewettite (?), fernondinite (?), and corvusite (?). Several unknown minerals in samples collected from various ore deposits during 1952 have not been found in sufficient quantity for chemical analyses and cannot be described as new minerals. In this group is a possible barium tyuyamunite.

R. B. Thompson, Jr. has separated and identified very small marcasite crystals from a blue-gray clay associated with melanovanadite and mottled red clay at the Mesa No. 1 mine in the Lukachukai Mountains, Ariz. He has also identified coffinite, pyrite, and a small amount of nickel-cobalt

arsenide, possibly rammelsbergite, from the gray portion of a mottled clay collected at the Corvusite mine, Beaver Mesa area, Utah.

Several studies of the clays and the clay minerals from the Colorado Plateau are in progress. R. B. Thompson, Jr. has made X-ray spectrometric patterns of about 25 red and gray clay samples associated with ore and has prepared several pairs of samples for chemical determinations.

M. D. Foster has found evidence that the "vanadium clay-like" mineral from Placerville, Colo., analyzed by V. North, is true roscoelite. This identification has also been reported by Prof. William Heinrich (University of Michigan). Thus, not all the vanadium clay mineral at Placerville is a hydromica. Several vanadium clay samples from the Plateau are being analyzed to determine whether they are roscoelite mica, vanadium hydromica, or a clay with included vanadium oxides.

M. E. Thompson has identified the mineral constituents, using an X-ray spectrometer, of the fine fraction of 96 samples submitted by R. A. Cadigan for the stratigraphic studies group on the Plateau.

The intensive study of the mineralogy of the Monument No. 2 mine and vicinity, Monument Valley, Ariz., by D. H. Johnson has already produced a large amount of data, of which the following seem especially noteworthy. Tyuyamunite, including metatyuyamunite, is the principal uranium ore mineral; carnotite proper is uncommon. Many specimens of uraninite have been found, surrounded by such secondary uranium minerals as becquerelite and uranophane. Most specimens of uraninite and some of the specimens of becquerelite show relic wood textures. Small amounts of arsenic and phosphate are present in zeunerite and autunite. Corvusite or a close relative is the most abundant uranium-free vanadium mineral; no vanadium clay mineral has been recognized

to date. Pyrite is relatively abundant; in some specimens it appears to be older than uraninite, in others younger. Pyrite with relic wood textures have been noted. Small amounts of other sulphides occur; some galena has been found within a uraninite specimen and small black sphalerite crystals were collected from a "log". The considerable iron content of this sphalerite indicates that it is the variety marmatite which suggests deposition at an elevated temperature.

Study of the distribution of the vanadium and uranium minerals at the Monument No. 2 mine suggests that as originally deposited they were generally ~~separate~~ being combined only after oxidation. There is also a suggestion that uranium tended to be deposited stratigraphically above the vanadium. Much, but far from all, of the ore occurs in what have been termed "logs" or "rolls", that is, ore-pods more or less cylindrical in shape. These "logs" generally contain ores of silicified wood, claystone, gray sandstone, or conglomerate. Much of this core material is very poorly cemented. An intermediate zone of tyuyamunite and/or limonite surrounds the core; and an outer zone of limonite impregnation grades into barren country rock.

Study of the mineralogy of the Skyline mine, in Monument Valley, Ariz. and of the Huskon claims near Cameron, Ariz., has also been started by D. H. Johnson in part for comparison with the Monument No. 2 mine. Both ~~these~~ mines have produced some uraninite; the Huskon claims have shown some interesting concentrations of nickel and cobalt.

During the period of this report, TEI-285, "Mineralogic study of some Jurassic and Cretaceous claystones and siltstones from Western Colorado and Eastern Utah," by A. D. Weeks was transmitted to the AEC.

A TEI report, "Identification and occurrence of uranium and vanadium minerals on the Colorado Plateaus," by A. D. Weeks and M. E. Thompson, written for the use of field geologists, may be available before the end of the 1953 field season.

Three TEI reports are in various stages of preparation for transmittal to the AEC: "Montroseite, a new vanadium oxide from the Colorado Plateaus" by A. D. Weeks, E. A. Cisney, and A. M. Sherwood; "Occurrences and properties of metatyuyamunite" by T. W. Stern; and "New occurrences of rauvite" by A. D. Weeks.

Plans for the general mineralogic studies during the next report period include field and office investigations to further define the relation between the oxidized and unoxidized ores, particularly within the Uravan mineral belt, as well as further investigation of the vanadium clay problem. The intensive study of the Monument No. 2 mine will be continued and additional mines may be mapped and studied intensively in order to relate the details of the mineralogy to the habits and history of the ores in hopes of determining the environment of ore deposition and paragenesis of the deposits.

Distribution of elements project, by E. M. Shoemaker

The distribution of elements project is planned to investigate the relations between uranium deposits, other types of ore deposits, the host sedimentary rocks, and igneous rocks in an effort to determine criteria for recognition of areas containing ore deposits. Special search is being made for new geologic environments favorable for uranium deposits and for new types of ore deposits. Results of preliminary studies are summarized in TEI-275, "Distribution of ore deposits and spectrographic analyses of some rocks and ores on the Colorado Plateau," by E. M. Shoemaker and

L. B. Riley, January 1953. A map of the "Uranium region of the Colorado Plateau," TEI-279, by E. M. Shoemaker and R. G. Luedke was transmitted to the AEC in January 1953; TEM-301, "Tectonic map of the Colorado Plateau," by R. G. Luedke and E. M. Shoemaker was transmitted in May 1953; both maps will be available to the general public as open file reports.

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

Colorimetric analyses have been obtained for suites of samples prepared from pulps of ore shipments to the uranium mills. In 66 samples, from mines widely scattered over the Colorado Plateau, arsenic was found to range in concentration from 20 ppm to 2,000 ppm and had a geometric mean concentration of 158 ppm. High values of arsenic were found chiefly in mines around the Henry Mountains, Utah, and around the La Sal Mountains, Utah. In 127 samples, selenium was found to range in concentration from less than 0.5 ppm to 350 ppm and had a geometric mean concentration of 9 ppm. In some of the mines at the Temple Mountain district, Utah, selenium is present in concentrations that under favorable conditions might be considered the threshold for possible economic value as a by-product in the uranium mills.

Statistical analysis has been begun on the distribution of elements within individual ore bodies. Tentative results of this study suggest that the metals are distributed systematically in the ore bodies and that the correlation between the metals can be related to the geologic environment of the ore bodies.

The average composition of Salt Wash sandstone was found to be strikingly close to the average composition of 32 formations from the Colorado Plateau ranging in age from pre-Cambrian to late Cretaceous. Of 17 elements compared, only four, sodium, magnesium, barium, and copper, showed more than a two-fold difference in concentration; only one element, copper showed more than a three-fold difference, from the average of the 32 formations. Copper was found to be eight times more abundant in non-uraniferous Salt Wash sandstone than in the average of the 32 formations. The average concentration of 30 ppm vanadium in the Salt Wash sandstone compares closely with the average concentration of 17 ppm in 32 formations. The average radioactivity of slightly less than 0.001% eU for the Salt Wash sandstone also compares closely with an average radioactivity of 0.002% eU for 11 formations ranging in age from Upper Triassic to Upper Cretaceous.

Reconnaissance mapping of the Ute Mountains, Colo. shows a system of faults on the north side of the mountains that may be related to the emplacement of the stock. Uranium deposits are found along the faults chiefly where the faults cut the Summerville formation. Non-radioactive copper deposits also occur along the faults and in a dike and laccolith that appear to lie along part of the fracture pattern. These geologic relations suggest that the uranium and copper metallization took place after or during the intrusion of the igneous rocks of the Ute Mountains and that the metals may have been derived from solutions related to the igneous rocks.

Reconnaissance studies of the lamprophyric rocks of the Navajo-Hopi Reservation have revealed that diatremes filled with volcanic debris have been mineralized with uranium at widely separated localities. The radioactivity of the unmineralized lamprophyres has been found to be uniformly low. The average radioactivity of 38 samples of minette, which is the most radioactive lamprophyre, is 0.0042% eU. Radioactive anomalies detected with

airborne equipment by the U. S. Geological Survey over the diatremes may indicate uranium deposits within the diatremes and all diatremes of the Navajo-Hopi Reservation may be worthy of investigation for uranium deposits.

Comparison of the minor elements in the bedded uranium deposits of the Colorado Plateau with barren "ore zone" sandstone indicates that certain elements, in addition to uranium and vanadium, are enriched in the ore deposits. This same suite of elements, excluding uranium and vanadium, shows higher concentration in the minettes of the Navajo-Hopi Reservation than in the diorite porphyries of the Ute Mountains.

A progress report summarizing the results of the Distribution of Elements work to date is in preparation. Two other reports, "Reconnaissance geology of the Ute Mountains" (TEM-624) and "Lamprophyre intrusions and associated uranium deposits of the Navajo-Hopi Reservation" are in preparation and will be submitted early in fiscal year 1954. Parts of the program that show special promise will be expanded during the 1953 field season. This work probably will include: (1) an evaluation of the uranium-bearing igneous rocks as economic sources of uranium, (2) evaluation of the use of trace metals in the sedimentary rocks as guides to ore, and (3) the evaluation of undeveloped mining districts by study of the composition of the ores.

Geophysical investigations
by R. A. Black

The Geological Survey has been actively engaged in a program of geophysical investigations on the Colorado Plateau since 1949. Geophysical investigations on the Colorado Plateau include the development of geophysical prospecting methods and the application of these methods to the search for uranium ore in individual districts.

Field work on the district studies project was recessed in December 1952 and was resumed in April 1953. The winter months were spent in computation of field data and in the preparation of reports on geophysical investigations made during the 1952 field season. Considerable time was also spent in study of interpretation techniques that could be applied to electrical resistivity data obtained on the Colorado Plateau.

TEM-589, "Geophysical Investigations on the Gramlich Group, Paradox district, Montrose County, Colorado," by R. A. Black is in preparation. Electrical resistivity and self-potential surveys were made on the Gramlich Group during the 1952 field season in conjunction with a development drilling project. The resistivity survey showed that the geologically favorable area for uranium deposits on the Gramlich Group is defined by a broad near-uniform zone of higher resistivity than that noted in the geologically less favorable areas. The self-potential survey showed that the uranium deposits on the Gramlich Group are associated with negative anomalies. The deposits seem to be arranged peripherally around the negative anomalies, and tend to concentrate down dip from them.

A report, "Geophysical investigations in the Koley Black area, Monument Valley, Arizona," by R. A. Black and W. H. Jackson is being readied for transmittal to the AEC. The Koley Black survey employed electrical resistivity, self-potential, and gravity measurements in an attempt to trace Shinarump-filled channels in the Moenkopi formation. Resistivity measurements proved most applicable and were found capable of delineating the channels in this area.

An electrical resistivity survey was made in the Monument No. 1 mine area, Monument Valley, Ariz. in an attempt to find a continuation of the

Monument No. 1 channel. The resistivity data obtained are being computed and are being interpreted by the use of Wetzell-McMurray theoretical resistivity curves. This will be the first time that this interpretation method has been applied to Colorado Plateau resistivity data.

A file report on the comparison and test of electrical resistivity measurements using commutated and direct current in Monument Valley in October 1952, has been prepared by H. C. Spicer and R. A. McCullough. Modifications of existing direct current techniques are suggested to improve the accuracy of the D. C. electrical resistivity measurements.

A paper entitled "Geophysical investigations of uranium deposits in the Colorado Plateau" was presented by R. A. Black at the annual meeting of the AIME in Los Angeles, Calif.

Field work was begun in April 1953 with a self-potential survey in the Happy Jack area, White Canyon, Utah. The uranium deposits in this area are associated with small amounts of sulphides. The survey was made to determine whether or not these uranium ore deposits with small amounts of associated sulphides could be detected by surface self-potential surveys. Preliminary examination of the data has shown small anomalies which may be associated with sulphide concentrations. Test drilling is planned by the AEC to determine the cause of these anomalies.

Self-potential, resistivity horizontal profiles, and resistivity depth measurements are presently being made in the Deer Flat area, White Canyon, Utah in an attempt to obtain geologic information prior to exploration drilling in this area.

Seismic refraction tests were made in four localities in the Monument Valley area during April 1953. The tests were made to determine the velocity

contrast between the Shinarump and the Moenkopi formation, and, in the event of a favorable contrast, to determine the ability of the seismic refraction method to trace channels. In the Nokai Mesa area, excellent results were obtained, probably as a result of the much greater Shinarump thickness and corresponding removal of the upper Moenkopi layers. In the Koley Black area, the interpretation of travel-time curves appears to indicate the positions of the channels. In the Hunt's Mesa and Monument No. 1 areas inconsistent results appear to be due to refractions from hard shale layers in the upper Moenkopi.

Field work was begun on a magnetic survey to determine the relationship of the Round Mountain stock, Castle Valley, Grand County, Utah to the La Sal Mountains. Field work has not progressed far enough to permit evaluation of the data.

An electric logging program was begun on the Colorado Plateau during the summer of 1952 to determine if uranium-vanadium mineralization in the Morrison formation alters its electrical properties to such an extent that such anomalies could be used as a basis for geophysical prospecting. Electric logging operations were carried out during the 1952 field season in various areas in the Morrison. Field operations were recessed from December 1952 to June 1953 and a laboratory study of the electrical properties of a group of diamond drill cores from the Morrison was carried out. Preliminary results indicate that at least a qualitative relation exists between resistivity and ore occurrence. Generally the resistivity of sandstone lenses in areas geologically unfavorable for ore was lower than the resistivity of sandstone lenses in areas favorable for ore; resistivity was highest in mineralized holes at the depth at which ore occurred. TEM-608, "Petrophysical studies of the Morrison formation," by G. V. Keller on the results of the field work has been transmitted to the AEC.

Plans for the next reporting period call for a continuation of resistivity and self-potential surveys in connection with exploration and district geologic studies problems. Refraction seismic surveys will be continued on an experimental basis. Research on the application of surface in-hole measurements to determine the extension of known uranium deposits will be carried out in addition to the regular electric logging program utilizing the results of last year's experimental work. The regular logging program in the Morrison formation will be continued and the electric logging may be started in the Shinarump conglomerate in the 1953 field season. Magnetic surveys will be made to determine possible relationships of igneous and sedimentary structures to uranium deposits.

Regional studies are planned for fiscal 1954 to establish the broader geologic and tectonic history of the Colorado Plateau. Such studies will, among other things, be concerned with analysis of regional magnetic, seismic, and gravity data with reference to the relationship between such features as buried igneous intrusives and salt plugs and the enclosing sedimentary rocks, and between basement topography and composition and the overlying sedimentary rocks. Gravity measurements are planned to supplement the broad regional data that has been made available on a confidential basis from oil companies. Additional aeromagnetic measurements totalling 10,000 square miles are planned for the 1953 field season.

Original-state core studies
by G. E. Manger

The objective of the original-state core study is to provide basic data on the physical and chemical properties of ore and country rock where the amount and composition of the interstitial water in the rock have not been

changed radically by the flushing action of a water-circulating drilling medium. Basic data such as the percent interstitial water saturation, chemical composition of the interstitial water and the host rock, and the porosity, permeability and electrical conductivity of the rock should assist materially in the interpretation of data obtained by current geophysical and geologic exploration. It is possible, too, that such data may reveal other relationships that would suggest new or modified techniques of exploration.

During the reporting period, laboratory investigations were made of cores obtained by air and oil-base-mud core drilling. These investigations included: (1) elastic constant determinations by the U. S. Bureau of Mines Eastern Regional Laboratory, (2) porosity, permeability and interstitial water determinations by the U. S. Bureau of Mines San Francisco Office, and (3) mineralogic and petrographic examination of well-mineralized portions of the core.

To date, preliminary results of the porosity, permeability and interstitial water analyses by the U. S. Bureau of Mines have been received. Figure 4 presents these data graphically. These and radioactivity analyses, together with some data derived therefrom, are shown in table 1. Some of the more important conclusions are:

1. The interstitial water content of the pore space in some samples (column 4) (sample tube numbers 66, 78, 79, 80) is very low. The percent saturation for the samples is certainly far below the "irreducible minimum" water saturation. In other words, water is probably present as discontinuous droplets in the sharper solid angles formed by the contacting surfaces of the mineral grains. As a consequence present-day flow of ground water through the rock represented by these particular specimens is improbable.

Table 1.--Core analysis and radioactivity data

drill hole LP-530, Uravan district, Montrose County, Colorado

Depth feet	Sample Tube Number	Radioactivity, in counts per minute $\frac{1}{2}$	Water content of pore space, percent	Water content of pore space, interstitial water (4)	Soluble solids (ppm), assigned to Pore space filled with water	Chloride, percent by weight in soluble solids	Porosity, percent of bulk volume	Permeability, Dry Air	Millidarcies 3 percent sodium chloride solution
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
200.00-200.91	1	421	37.1	82,700	30,600	5.40	15.8		
200.91-201.39	2	385	33.3	140,000	46,600	2.77	12.5		
228.90-229.90	32	408	28.5	102,000	29,600	2.53	14.4		
Air-cored to 233. Oil-base-mud cored below 233.									
251.06-252.04	57	439	22.6	153,000	34,600	1.46	11.7		
259.06-260.17	66	391	2.3	450,000	10,200	3.46	20.1		
266.48-267.42	74	388	32.9	65,300	21,400	6.66	16.7		
270.25-271.23	78	390	3.1	479,000	17,850	1.53	20.4	142	
271.23-272.15	79	360	2.0	451,000	9,020	1.75	19.4	359	
272.15-273.00	80	385	4.2	277,000	11,650	6.20	20.6	1,050	
273.00-273.99	81	390	19.1	91,000	17,400	.97	17.8	365	
273.99-274.93	82	397	16.9	71,000	12,000	1.01	20.9	348	
274.93-275.88	83	390	19.4	101,000	19,600	.75	21.4	643	

Table 1 (Con't)

Depth, feet	Sample Tube Number	Radioactivity, in counts per minutes $\frac{1}{2}$	Water content of pore space, percent	(4)	(5)	(6)	(7)	(8)	(9)	(10)
			Measured interstitial water (4)	Soluble solids (ppm), assigned to Pore space filled with water	Chloride, percent by weight in soluble solids	Porosity, percent of bulk volume	Permeability, millidarcies	Dry Air	3 percent sodium chloride solution	
275.88-276.73 Middle	84	772	41.0	41,500	17,000	.72	20.2	182		
275.88-276.73 Bottom	84	980	45.4	41,200	18,700	2.74	18.3	29.2		6.3
276.73-277.66 Top	85	2,318	34.1	67,400	23,000	.79	15.5	30.4		
276.73-277.66 Middle	85	10,487	78.1	28,900	22,600	.80	15.3	3.3		
276.73-277.66 Bottom	85	17,808	86.6	34,700	30,050	.22	21.9	44.5		8.8
277.66-278.46 Top	86	920	37.4	30,400	11,400	1.10	20.8	660		86.1
277.66-278.46 Middle	86	884	23.9	64,100	15,300	8.81	19.4	174		
277.66-278.46 Bottom	86	453	24.8	70,400	17,300	1.82	16.1	365		
278.46-279.38	87		20.1	107,000	21,500	1.67	15.3	225		
279.38-280.23	88	--	--	--	--	--	--	--		
280.23-281.09	89		18.6	81,800	15,200	2.48	18.4	910		
281.09-281.94	90		16.4	104,000	17,050	2.08	18.3	1,070		

Table 1 (Con't)

Depth, feet	Sample Tube Number	Radioactivity, relative, in counts per minute \bar{x}	Water content of pore space, percent	Soluble solids (ppm), assigned to Measured Pore space interstitial filled with water (4)	Chloride, percent by weight in soluble solids (7)	Porosity, percent of bulk volume	Permeability, Dry Air 3 percent sodium chloride solution (10)	
(1)	(2)	(3)	(4)	(5)	(6)	(8)	(9)	
281.94-282.90	91		22.1	77,600	17,150	2.29	16.8	260
282.90-283.00		Core lost						
283.00-283.98	92		46.2	42,500	19,600	1.64	19.4	36.7
283.98-284.93	93		29.2	55,800	16,300	1.86	22.0	542
284.93-285.87	94		26.3	59,000	15,450	2.91	21.8	404

\bar{x} 735 counts per minute = 0.020 percent eU_3O_8
 943 " " = 0.035 " " "

Other samples (column 4) contain appreciably more water in the pore space, but in these samples also the percent water saturation may be at or below the "irreducible minimum". If so, a continuum of water in the rock represented by these samples is not present, and ground water is probably not moving through the rock. Capillary pressure or other suitable laboratory tests will be needed to determine the "irreducible minimum" water saturation for representative samples.

The more radioactive samples, and particularly those from the ore zone (column 4, sample tubes number 85), show a high percent saturation in the pore space which may be due to contribution of "water of crystallization" from clay-like minerals associated with the ore.

2. When the recovered soluble solids are "dissolved" in the recovered water, expressed as percent saturation of pore space in column 4, some impossibly high concentrations of soluble solids in interstitial water are obtained (column 5). Some of the interstitial water solutions may be supersaturated, or more likely, salts may be present as precipitates in the pore spaces in the formation.

3. If the soluble solids (column 5) are hypothetically dissolved in water occupying 100 percent of the pore space (column 6), the solution concentrations become more uniform and range from 9,000 to 30,000 parts per million soluble solids. Thus it seems that the varying concentrations of column 5 may be due to evaporation of interstitial water.

4. The maximum chloride content in the samples studied (column 7) is less than 9 percent of the total soluble solids and the average is only 2 percent, whereas the chloride content of sea water exceeds 50 percent of the total dissolved solids. It seems, therefore, that the interstitial water in

these sediments is not derived from normal sea water, nor indirectly from brackish water. The low chloride content of the ore rock (sample tubes 85) may be due to chemical reaction among the ore, associated minerals, and the interstitial solutions.

5. The low air permeability in the ore zone (column 9, sample tubes number 85) may be due to cementation arising from emplacement of ore and associated minerals. Liquid permeability (column 10) determined by sodium-chloride brine is roughly 20 percent of air permeability. Theoretically, the air and liquid permeability should be equal. Reduction of liquid permeability is attributable usually to the swelling of clay minerals.

Laboratory work for the next half year will include completion of analyses by the U. S. Bureau of Mines on cores obtained during the 1952 field season, and further measurements of other physical properties such as elastic constants and electrical conductivity, and chemical, spectrographic, radioactivity, and mineralogic examination of the rock and interstitial water. During the 1953 field season it is planned to core-drill two holes through unoxidized ore in the Uravan area. An oil-base drilling mud will be used. Physical and chemical analyses similar to those described above, will be made on the unoxidized ores.

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

The objectives of work in the Pumpkin Buttes area are: to search for uranium deposits; to study the distribution of the rocks in which uranium occurs; to study the habit of occurrence of the uraniferous deposits; and to outline the areas favorable for the occurrence of additional uranium deposits.

The Pumpkin Buttes area includes about 650 square miles in Johnson and Campbell Counties, Wyoming. During the 1952 field season the geology of about 100 square miles was mapped in some detail on aerial photos and another 130 square miles was mapped by reconnaissance methods.

Uraniferous deposits in the area are of two types: (1) small irregularly shaped concretionary masses containing much manganese and iron and having a very high uranium content, and (2) disseminated uranium minerals with little or no manganese and iron. The deposits of disseminated uranium minerals are similar in many ways to deposits in the Colorado Plateau. Both types of deposits are found in sandstones that ordinarily are lenticular, cross-bedded, medium- to coarse-grained and reddish-gray in color. The sandstones containing the uranium deposits are in the Wasatch formation 450 to 900 feet above the base. The presence of the reddish-gray sandstone containing carbonaceous material is a useful guide at most places to favorable ground for the concretionary deposits. The deposits of disseminated minerals were discovered late in the field season and not enough information is available to identify the features that would be useful in searching for more deposits of this type.

TEM-572, a preliminary report on the results of the field investigations, was transmitted to the AEC on January 16, 1953. Since that time all field data has been compiled and a more detailed report is about completed.

During the field season of 1953 geologic mapping will be continued in the Pumpkin Buttes area. Parts of Sussex No. 1 SE, Butte No. 2 SW, and Sussex No. 1 NE, 7½-minute quadrangles will be mapped in detail to further study the distribution of the ore-bearing sandstones, and the enclosing rocks, and to study the relation of uranium deposits to this distribution. The areas

chosen for mapping include a number of the concretion-like pods and all, so far known, of the disseminated deposits. More detailed mapping, at a scale of 1 to 1,200 or less, will be done at and in the vicinity of the more important deposits of uraniferous material.

In addition, further studies of the stratigraphy of the Wasatch formation and the relation of uraniferous deposits to stratigraphy will be made.

Black Hills, South Dakota
by V. R. Wilmarth

The immediate objectives that have governed the type of investigations carried on in the southern Black Hills during the past six months have been to determine: (1) the stratigraphy of the Lakota and Fall River sandstones, (2) the relationship, if any, of the ore deposits to structural and stratigraphic anomalies and irregularities, (3) the relationship of uranium to its decay products, and (4) the mineralogy of the deposits.

Detailed studies of the outcrops and of diamond drill core, have shown that the Lakota sandstone in the Long Mountain area contains two principal ore-bearing zones. One of these ore-bearing zones is a massive sandstone at the base of the Lakota sandstone and predominantly is composed of fine sand and interstitial clay. In Craven Canyon it is about 100 feet thick but thins rapidly both to the east and to the west. The uranium content ranges from 0.039 to 0.47 percent and from 0.11 to 0.75 percent V_2O_5 . The other mineralized sandstone occurs about 50 feet stratigraphically above the basal sandstone. This bed is widespread and ranges from 20 to 105 feet in thickness. It is composed of thin interbedded, fine- to medium-grained, sandstones that contain abundant altered feldspars, chert, and carbonaceous

fragments. The sandstones generally are light grey but locally are light purple. The color has no apparent relation to the ore deposits. The uranium and vanadium content of samples from this bed are comparable to those of the basal sandstone.

Analytical data indicate that the average U_3O_8 - eU_3O_8 ratio is less than 1 in the cores and greater than 1 in the surface samples. The V_2O_5 - U_3O_8 ratio is about 2 to 1, in the cores but less than 2 to 1 in surface samples.

Preliminary study of the mineralogy of the ores from the Edgemont area has been completed. At the Pabst No. 3 mine, dark-red to black crystals of meta-hewettite, a secondary calcium-vanadate, occur as isolated clusters and as coatings as much as one-fourth inch thick on a glassy, colorless, botryoidal mineral that is probably opal. A rounded mass of a dark brown-black mineral that optically resembles rauhite, a calcium uranium-vanadate, is in the center of many of the isolated clusters. Meta-tyuyamunite, rauhite, hewettite, meta-hewettite, carnotite, and autunite have been tentatively identified in specimens of uranium-vanadium-bearing Fall River sandstone from the ore zone at the Matias Peak No. 1 claim. Autunite occurs as thin coatings and as doughnut-shaped masses on a light to dark gray, paper shale that forms an impervious layer at the bottom of the ore zone. No autunite was noted in the sandstone. The yellow uranium minerals--carnotite and meta-tyuyamunite--were, in general, the first deposited. They occur as grain coatings, as fracture fillings, and as disseminated flakes in the sandstone. The meta-hewettite and hewettite occur as thin coatings on the sand grains and almost always coats the yellow uranium minerals. Rauhite occurs as botryoidal masses on the other minerals and appears to have been the last mineral deposited. Continued study of specimens from other mines in the area may result in a full knowledge of the paragenesis of the ores.

Silver Reef district, Washington County, Utah
by Frederick Stugard

The Silver Reef project will be completed by the transmittal of TEI-254. The report gives the results of the diamond-drilling program in 1951 and a re-examination of the mine workings in May 1953. (See TEM-214.)

The geologic conditions in the Silver Reef district are such that uranium ore can be produced only by selective mining of small lenses of ore-bearing sandstones and shales within the Chinle formation. The largest ore body found and mined to date was approximately 50 by 60 feet, and 1 to 3 feet in thickness. The ore produced has come from 9 to 25 feet below the surface and is in this respect similar to the silver deposits mined in the nineteenth century, which were shallow and decreased in grade with depth. Uranium-vanadium minerals occur on fracture surfaces for a few feet beyond the main ore-bearing pods, thus showing greater mobility than the silver minerals described in old mining reports.

The lithology of the reef-forming sandstones of the Chinle formation is so variable that an individual bed can rarely be traced for a quarter of a mile. Therefore, favorable ground for prospecting can only be projected for short distances from any ore bodies discovered in the future. Detailed exploration is needed in advance of mining operations to reduce the tonnage of waste rock removed. The remaining areas in which exploration might duplicate known ore pods by new discoveries are the Big Hill area, and adjacent to the recently exploited pods of ore at the Vanderbilt mine and the Leeds Uranium mine. The core drilling in 1951 recorded the strata around Pumpkin Point satisfactorily and shows the difficulty of lithologic correlations over even short distances. Development work on any new ore bodies would best be accomplished by wagon drilling.

Within the Silver Reef district, further prospecting can best be carried on by wagon drilling on a 20-foot grid, or closer spacing, around the already exploited deposits at the Leeds Uranium mine, Vanderbilt mine, and westward from Pumpkin Point onto Big Hill. A 5-foot grid is required to outline any ore bodies prior to mining. Near the Silver Reef district, prospecting can best be carried on by radiometric traversing in the Chinle formation east of the Hurricane fault, in the Cenozoic formations in contact with the Pine Valley laccolith, and the Shinarump conglomerate outcrops southward from Silver Reef.

The Silver Reef district may in the future produce an additional tonnage of uranium roughly equal to that already produced, but probably not at a profit to the operators. This uranium would probably come from small lots of hand-sorted ore produced by excessive labor. The possibility of the district supporting sustained uranium mining operations is exceedingly remote, although hand specimens of marketable grade may be submitted from time to time.

After completion of this Geological Survey project, it is planned to follow private developments in the district informally and to make a brief geological study of any new ore bodies found.

RESEARCH FOR AND GEOLOGY OF URANIUM IN VEINS,
IGNEOUS ROCKS, AND RELATED DEPOSITS

Reconnaissance

Central Mineral Belt, Colorado
by C. T. Pierson, Q. D. Singewald, and M. G. Dings

Field work in the Alma and St. Kevin districts was completed in 1952. In the Alma district, Park County, pitchblende is associated with Tertiary veins. Secondary uranium minerals, as yet undetermined, are associated with pitchblende in several occurrences. Although none of the known occurrences in the Alma district is of commercial importance, the district is considered a favorable area in which to prospect for uranium ore because 24 of the 43 localities examined show anomalous radioactivity. Samples from these 24 localities contained from 0.001 to 1.66 percent U.

In the St. Kevin district, Lake County, 122 weak radioactive anomalies were found. Most of the anomalous radioactivity is in igneous and metamorphic rocks of pre-Cambrian age, but some anomalous radioactivity is in metalliferous veins of Tertiary age. Samples of altered granite or schist contain as much as 0.065 percent U, probably in the form of secondary uranium minerals. Samples of vein material contain as much as 0.013 percent U also probably as secondary uranium minerals.

At a few localities, uranium-bearing minerals have been identified. They are found as disseminations and fracture coatings in igneous and metamorphic rocks, and are probably present in the radioactive vein material. Torbernite is the most common uranium-bearing mineral, but metatorbernite, autunite (?), and a uranium variety of florencite are sparsely distributed.

The known uranium occurrences are not of commercial importance. However they are for the most part in non-glaciated terrane which has been subjected to a very long period of weathering, during which the uranium content of material near the surface may have been greatly reduced by chemical leaching. Occurrences of even small quantities of uranium minerals might be related to stronger, primary concentrations at depth.

During the summer and fall of 1952, the Montezuma district, Summit County, and the Garfield and Taylor Park quadrangles, in Chaffee and Gunnison Counties, were radiometrically examined. The Montezuma district contains abundant fissure veins that cut pre-Cambrian gneiss and Tertiary quartz monzonite. The typical vein minerals are galena, sphalerite, pyrite and chalcopyrite in a quartz-barite gangue. Abnormal radioactivity was detected at 2 prospects on 2 different veins on Glacier Mountain, but the uranium content of both veins is too low to be commercial at present.

In the Garfield and Taylor Park quadrangles, the prevailing structures are northwest-trending folds and faults. The principal ore minerals, including sphalerite, silver-bearing galena, gold-bearing pyrite, and limonite, occur chiefly as replacement bodies in limestone and as shoots in pyritic quartz veins. Anomalous radioactivity is uncommon; weak radioactivity was detected at only 4 widely separated localities in the Garfield quadrangle--Madonna, Silent Friend, and Bon Ton mines, and the Mount Antero region. The uranium content of samples from these localities is low. No further investigation of the radioactive materials in the region is planned.

General geologic studies

Relation of uranium to post-Cretaceous vulcanism

by R. R. Coats

As outlined in TEI-310, this project was prompted by the observed spatial relationship between the regional distribution of Tertiary volcanic rocks and structurally controlled uranium deposits in the southwestern part of the United States, and the fact that some of these uranium deposits occur in, or appear to be genetically related to, intrusives of Laramide or later age. Three aspects of the problem were to receive detailed study: (1) regional variations in the primary distribution of uranium in igneous rock bodies, and the relation to the variation in the distribution of other elements; (2) primary variations in the distribution of uranium within individual igneous rock masses; (3) epigenetic variations in the distribution of uranium in igneous rock bodies.

The field work in the fall of 1952 was largely sampling and field examination directed toward the study of the first of these problems. The Denver laboratories of the Geochemistry and Petrology Branch analyzed about 50 samples for eU, U, and by quantitative spectrographic methods, for Mn, B, Be, La, Li, Nb, Sn, Ta, Th, and W. Statistical analysis of the results is incomplete, but there is a strong suggestion of a correlation between the uranium content and the content of the elements that are known to be enriched by pegmatitic processes. The range of variation found in parts per million for the several elements is Mn, 100-700; B, 10-100; Be, 2-10; La, <40-100; Li, 40-400; Nb, 2-70; Sn, <4-10; U, <1-40.

There is also an indication of a broad regional pattern in the grouping of most of these elements, but additional, more widely distributed samples will be necessary to substantiate this tentative conclusion.

Field work, to be resumed about July 1, will be directed again toward determining the pattern of regional distribution. As opportunity offers, study of the relation of the type of alteration to radioactivity also will be undertaken.

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

The objectives of this project are: (1) To test the validity of the present ideas on the zonal position of uranium deposits in metalliferous areas (TEI-270). The salient features have been presented principally in a report by King, Leonard, Moore, and Pierson (USGS Circ. 215) and in a talk delivered at recent meetings of the Geological Society of America by Leonard (Geol. Soc. Am. Bull., v. 63, pp. 1274-1275, 1952). (2) To find and make appropriate investigations of new uranium deposits. The emphasis of this project has been on the development of geologically-based prospecting guides to delimit areas most favorable for the occurrence of uranium deposits within metalliferous districts (TEM-521).

During the winter months, data were compiled on the zonal distribution of metals in the Wallapai district, Arizona; the Goodsprings district, Nevada; the Bohemia district, Oregon; the Gold Hill district, Colorado; and scattered metalliferous districts of the southwestern states.

Wallapai district, Arizona

Dings (USGS Bull. 978-E, 1951) noted the rough zonal distribution of metalliferous deposits in the district, Campbell computed metal ratios Pb/Cu,

Zn/Cu, Zn/Pb, Au/Ag, Au/Cu, and Ag/Cu for mines in the district, using production figures given by Dings (Bull. 978-E, p. 147). Later work of the AEC disclosed several interesting radioactive deposits. With considerable hesitation, owing to inadequate data on metal ratios in the critical areas, we might infer that the significant radioactive deposits are in areas where the metalliferous veins have a high or unknown Cu/Pb ratio (Cu/Pb, x^{Pb}/x) and an intermediate or unknown Au/Ag ratio (Au/Ag, $1/xx$). This is crudely analogous to the pattern at Central City, Colorado, though at Central City the intermediate zone carrying pitchblende presumably had a higher Cu/Pb ratio and a Au/Ag ratio closer to 1/1. Data on the Zn/Cu and Zn/Pb ratios are lacking for the critical area at Wallapai. Dings (Bull. 978-E, p. 142) noted that chalcopyrite is one of the more important primary minerals and apparently the most important primary copper mineral at Wallapai.

At least one other area in the Wallapai district, centering about 1.5 miles southeast of Chloride, shows a similar high Cu/Pb ratio and an intermediate Au/Ag ratio. Though this area was also covered by the AEC's systematic radiometric reconnaissance, significant anomalous radioactivity was not detected.

Central City district, Colorado

Recent discoveries of pitchblende suggest that the limits of the intermediate zone, favorable for pitchblende deposits, should be broadened slightly from those suggested earlier in Circular 215. However, the general relation of pitchblende to mineral zoning still is applicable as originally stated.

Field work in the Oregon Cascades, earlier planned for the summer of 1953, is cancelled as the project will probably be recessed on July 1.

A report summarizing existing knowledge on the zonal distribution of uranium deposits may be prepared next winter.

Radiometric reconnaissance of the Gold Hill mining area, Boulder County, Colorado, by R. H. Campbell

The month of April was spent in radiometric reconnaissance in the Gold Hill mining area, Boulder County, Colorado. This area was selected because it shows some lateral zoning of sulfide minerals associated with telluride ores of gold and silver. In addition, the reported occurrence of pitchblende in the Black Cloud mine is in the area of mixed gold-lead-silver-tellurium veins. Thus it seemed reasonable that further radiometric reconnaissance in the district might disclose additional significant radioactivity and occurrences of pitchblende that might be related in some way to the pattern of sulfide zoning, or to the distribution of the telluride-bearing veins. This zonal pattern is described below.

Two small centers (the area of the Twin and Klondike veins in the northwest part of the area, and the area of the Grand Republic mine to the southeast) contain veins in which the ores were predominantly pyrite-gold and/or free gold. These "gold centers" are partly surrounded by veins containing tellurides accompanied by base-metal sulfides, including sphalerite and galena. A belt of telluride veins lacking important quantities of sulfide minerals trends northeast between the two "gold centers" and their peripheral telluride-sulfide veins.

Several local radioactive "highs" of from 0.10 to 1.50 mr/hr were

observed in the area, but most of them could not be related to any visible uranium mineral. The present investigation disclosed four occurrences of radioactivity, associated with visible black minerals tentatively identified as pitchblende, which had not been reported previously. All four of these occurrences and all the previously reported occurrences of pitchblende are within the belt of mixed base-metal sulfides and tellurides that is peripheral to the northwestern "gold center".

Nearly all of the veins in the Gold Hill area are from 0.01 to 0.03 mr/hr higher in radioactivity than the country rock surrounding them. The radioactivity of the country rock in the area, predominantly Boulder Creek granite (Goddard, 1940, Colo. Sci. Soc. Proc., v. 14, no. 4), averages around 0.020 to 0.025 mr/hr, rising to 0.04 locally, and reading as high as 0.08 on the most radioactive of the pegmatites observed. All the veins have radioactivity of 0.03, at least locally, and most of them average 0.04 to 0.06 mr/hr along their entire exposures. In some veins, radioactivity appears to increase in direct proportion to the amount of vein material present. That is, radioactivity increases in or near stopes and visible swells on the vein. However, this relationship is not consistent throughout the district, as many of the local "highs" appear to have no relationship to the amounts of material present in the veins in which they occur. Another feature of some of the veins is an increased radioactivity at splits and intersections. This relationship, also, is not consistent throughout the district, and is apparently a feature of particular individual veins. There is no apparent relationship of these radioactive veins, or of the local "highs" not associated with visible uranium minerals, to the lateral zoning present in the district.

The results of the present investigation suggest that the more important concentrations of uranium in the district are in the group of telluride-sulfide veins peripheral to the northwestern "gold center". However, the relationship of uranium to this telluride-sulfide zone is still not clear. As radiometric sampling of the district as a whole was not as complete as would be desirable, it is quite possible that significant concentrations of uranium minerals might be present throughout the area, with a more random distribution than that suggested by present data.

Therefore, if further prospecting for uranium is done in the Gold Hill area, the northwestern "peripheral zone" is probably the most favorable area for intensive work. However, the remainder of the district should not be disregarded. If the size and extent of the known deposits is considered indicative of the size and extent of the deposits remaining unknown, it is inferred that very few, if any, uranium ore bodies in the district are of sufficient size and extent to be economically important by themselves. However, if the district should again become active in mining gold and silver, lead and/or zinc, then possibly some uranium could be produced as a by-product.

Frequency distribution of uranium with relation to
enclosing wall rocks
by J. W. Adams

During the period investigations have been continued on the uranium-bearing deposits in the Golden Gate Canyon and Ralston Buttes areas, Jefferson County, Colo. A brief field study was made of the rocks and structural features in the vicinity of the Golden Gate Canyon deposits, but most of the work has been a laboratory study of previously collected material.

Of the eight known uranium occurrences in Jefferson County, only the Schwartz or Ralston Creek mine is being actively prospected and an application for DMEA assistance has been made by the lessee. Recent work at the mine has exposed a 7-foot width of pitchblende-torbernite ore that contains 1.68 percent U. A 2-foot channel sample in this zone contains 4.32 percent U. The extent of the ore is not known, but the occurrence is in a strong shear zone that is known to be radioactive along several hundred feet of strike length. As much as 0.14 percent V_2O_5 was found in samples of the ore, but the nature of the vanadium mineral has not been determined. The ore in this deposit is more siliceous and contains less carbonates than the other pitchblende-bearing breccias examined in the area; a crystalline potash feldspar, rare in the other deposits, is a common gangue mineral at the Schwartz mine. A detailed study of the wall rocks and ores from this mine has begun.

District studies

Colorado Front Range by P. K. Sims

The Central City district in the Front Range has been the principal domestic source of high-grade pitchblende ore, and accordingly in fiscal year 1953 a detailed study of an area of about 65 square miles between Georgetown and Central City was undertaken to evaluate the potential of this area for new production. The objectives of this investigation are mainly to: (1) find uraniferous deposits, (2) determine the geologic settings of the deposits, (3) define ore guides and controls, (4) determine the origin of the uranium, and (5) evaluate the uranium resources.

During the past half-year, laboratory investigations were begun on the ores and the country rocks, the exploration projects were followed and detailed geologic mapping and sampling were done in critical areas.

Exploration financed by DMEA or the AEC is, or has been, in progress at the East Calhoun, Gold Rock (Springdale), Cherokee (Spread Eagle), Martha E, and Golconda mines. High-grade lustrous, pitchblende ore was found in the East Calhoun and Cherokee mines, but no ore has been shipped as a result of this work.

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

Exploration of the Wood vein at the East Calhoun mine, financed by DMEA, continued during this report period. A small pod of high-grade pitchblende ore, 8 feet long, 8 feet high, and 1 to 6 inches thick was encountered in the west drift on the 583-level, 506 feet west of the cross-cut from the Calhoun vein to the Wood vein. The ore is high-grade, massive, and lustrous. The highest assay (6-inch channel sample) gave 9.30 percent eU and 9.94 percent U. The pitchblende is on the footwall side of the vein intimately associated with white pyrite. A 3-inch layer of chalcopyrite and yellow pyrite occurs on the hanging wall side of the vein. In the vicinity of the uranium ore small amounts of sphalerite and galena are found around chalcopyrite crystals, and vugs contain sphalerite crystals and comb quartz. Some tetrahedrite is present, and a brittle wire mineral, tentatively identified as the bismuth telluride, tetradymite, was found in one vug. The vein in the area of the pitchblende pod contains considerable good grade copper ore and, at places, gold ore. According to the mine superintendent, free gold is present in this part of the vein.

The pitchblende pod appears to lie on the projection of the shoot outlined in the Wood mine (Moore and Butler, USGS Circular 186, 1952), which rakes about 45° to the west. Accordingly, it has been recommended to DMEA that further exploration be done to explore this favorable ground above the 583-level.

The recent discovery in Eureka Gulch of 4 mine dumps--Bullion, Boodle, Carrol, and Rara Avis (?)--with significant radioactivity makes this area a potentially important source of uranium that should be explored. The following assays were obtained from grab samples of selected dump material.

<u>Mine</u>	<u>Equivalent uranium</u>	<u>Uranium</u>
Bullion	6.7	6.87
Boodle	.013	.003
Carrol	1.7	.025
Do.	.93	.68
Rara Avis (?)	.80	.59
Do.	.17	.15
Do.	.22	.03
Do.	1.7	0.94

Pitchblende has been identified from the Bullion, Carrol, and Rara Avis dumps. To judge from dump material, it is associated principally with galena and sphalerite.

The Eureka Gulch area is within the intermediate zone, as outlined by Leonard (abstract) 1952, on the north side of the central pyritic area centering around Quartz Hill, and it is expected that further reconnaissance in this region will disclose additional pitchblende occurrences. The area also is near the Nigger Hill bostonite dike (Phair, TEI-247).

Pitchblende is present in the Cherokee (Spread Eagle) mine in Pleasant valley, and the mine is being opened and explored by AEC. The pitchblende is exposed for a vertical distance of about 25 feet in the shaft wall over a width of 3 to 6 inches. A grab sample of dump material contained 3.48 per cent U.

Exploration by the AEC of the Gold Rock (Springdale) mine, exposed a small lense of pitchblende ore on the second level west.

A yellow uranium mineral, identified by the AEC as zippeite $[(UO_2)_2(SO_4)O \cdot nH_2O]$, has been observed at places on the walls of the Diamond Joe adit in Virginia Canyon. An interesting feature of this mine is the occurrence of small amounts of native copper, heretofore not described from the district.

Dumont-Fall River area, by F. B. Moore

Sampling of the radioactive vein at the Golden Calf mine near Dumont indicated that the vein is not of ore grade. The samples collected were out of equilibrium by a ratio of nearly 2 to 1 and assayed in the order of 0.0X percent U over a 1-foot width.

Freeland-Lamartine district, by J. E. Harrison

Exploration work at the Martha E mine, Clear Creek County, Colo., financed by DMEA, was concluded on May 15, 1953. The inclined winze was extended 85 feet to a point 100 feet below the adit level (TEM-291) as measured in the plane of the shear zone; and 66 feet of drifting and cross-cutting was done on the new level at the bottom of the winze. No ore of minable grade was encountered.

Torbornite, metatorbernite, autunite, and sooty pitchblende occur along the vein in a zone that ranges from 1 to 26 inches wide. Torbernite, metatorbernite and autunite occur along the footwall of the main vein and are concentrated near intersections between the main vein and minor shears. Sooty pitchblende occurs along crosscutting fractures in the main vein, in thin stringers parallel to the main vein, and disseminated through gouge near vein intersections and splits. The main vein appears to

become stronger with depth and contains quartz, pyrite, chalcopyrite, galena, and sphalerite below 49 feet in the winze. Because of post-mineral shearing, these minerals occur only intermittently as lenses and pods in the shear zone.

Summary

Although there has been no new production from the mines in the Central City-Idaho Springs district, several radioactive veins have been discovered during the past half-year, and some of these appear to be potential sources of high-grade uranium ore. At the East Calhoun mines, a few tons of high-grade ore has been stockpiled.

All the new discoveries of potential importance are within the intermediate (favorable) zone of Leonard and are near radioactive bostonites (Phair, TEM-247). The detailed field studies of these favorable areas indicate that the radioactive deposits occur in "clusters".

It is anticipated that the Eureka Gulch and the Pleasant valley areas eventually will be of comparable importance to the Quartz Hill area, but an evaluation of these new areas cannot be made until several of the mines are opened.

The limited study of individual pitchblende deposits suggests that the pitchblende occurs as small pods within larger "ore shoots"; and delineation of these shoots within the active mines for exploration should materially reduce exploration and development costs. Little yet is known concerning structural and lithologic controls and the nature of the wall rock alteration.

Plans

The plans for the next half-year are to: (1) Continue aerial geologic mapping in the Central City-Georgetown area. The mapping in the Central City region will be extended northward beyond Eureka Gulch, eastward to the Justice Hill area, and southward to Pleasant Valley and Gilson Gulch; the mapping in the Dumont area will be extended northward into Fall River, and also westward; and the mapping in the southern part of the region will be extended into the Chicago Creek area and will include the Martha E area. (2) Continue systematic radiometric reconnaissance. It is planned to complete this fiscal year a quantitative survey of the entire 65 square mile area. (3) Continue geologic mapping and study of all accessible mine openings, particularly those known to contain pitchblende-bearing veins. (4) Continue fundamental geologic studies of the ores and country rocks to provide data on ore guides and controls, paragenesis, and source of the uranium. (5) Begin an intensive study of wall rock alteration associated with the ore deposits.

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

The petrographic study of samples collected in 1952 from the middle and northern parts of the Front Range Mineral Belt indicated that the relationship between petrographic type and radioactivity observed in the Central City district holds true for the broader region. Good quartz bostonites are scarce outside the Central City district, but these few include nearly all dikes of medium to high radioactivity in the region. We cannot at present say for certain that all quartz bostonite dikes in the region are radioactive. We do know that many porphyries lumped as

"bostonite" in the past are actually quartz-poor trachyte, and/or monzonite.

X-ray spectrometer studies of the phenocrysts in the various porphyries have confirmed our observation that the phenocrysts in the quartz bostonites are of potash feldspar. The potash feldspar contains an average of 30 percent sodalase and is therefore a potash cryptoperthite. This helps to explain the discrepancy between the norm and mode in these rocks. Phenocrysts from the other porphyries tested to date yield much more variable results but all are on the high-soda side (soda-cryptoperthites). The method used was that described by Bowen and Tuttle in 1950.

In order to find out whether there is any connection between uranium- and thorium-rich centers of intrusion in the Front Range and the isotopic composition of the associated vein, leads of 12 selected galena samples collected during 1952 have been analyzed. The lead iodides separated from these have been sent to Oak Ridge. Of these 8 are Tertiary and 4 are pre-Cambrian. This reconnaissance study is being carried on in active cooperation with L. R. Stieff and Ralph Cannon.

Ralston Buttes district, Colorado
by D. M. Sheridan

Because the Ralston Buttes district appears to be potentially important as a producer of uranium ores, several investigations have already been started and a district-type study is scheduled to start in fiscal 1954. During the past four months E. P. Beroni has continued intermittent radiometric reconnaissance in the district (see section Regional Reconnaissance in U. S., Colorado-Wyoming district, by King and Beroni), and J. W. Adams

has continued his investigation of the ores of the pitchblende veins.

Pitchblende, associated with base-metal sulfides, is known from eight localities in the Ralston Buttes district, Jefferson County, Colo. (Adams, Gude, and Beroni, TEM-154). The known deposits are in carbonate-rich shear zones that cut pre-Cambrian igneous and metamorphic rocks. One possibility is that uranium deposition in the Ralston Buttes district may be genetically related to the Leyden carnotite deposit, which occurs in or near a fault in sandstone and silicified coal less than four miles east of the district (Gott, TEM-132).

The main objectives of the district-type study will be: (1) to evaluate the uranium potential of the quadrangle, (2) to search for new uranium deposits, (3) to investigate the geological and structural factors that controlled the localization of pitchblende mineralization, (4) to study the possible genetic relationship of the pitchblende to the nearby Leyden carnotite deposit, and (5) to investigate significant beryl-chrysoberyl pegmatite deposits.

During the first part of fiscal 1954, geologic and radiometric reconnaissance will be undertaken in the district. Mapping of the known significant areas will be at scales of 1:6,000 and 1:240. This initial large scale mapping will be followed by areal mapping at 1:18,000 scale for the entire Ralston Buttes $7\frac{1}{2}$ minute quadrangle-- mapping that will be continued in fiscal 1955. Any significant deposits or areas found during the areal mapping will be mapped in detail later in the project. Specific plans for limited physical exploration--bulldozing or trenching, and minor mine rehabilitation--will be submitted after the first six months of fiscal 1954.

San Juan Mountains, Colorado

Reconnaissance, by C. T. Pierson

Laboratory analyses of the most radioactive samples collected in the western San Juan Mountains show that the uranium contents range from 0.002 to 0.35 percent. None of the occurrences is of commercial interest, but the analysis showing 0.35 percent U, from the Lark mine, San Juan County, indicates that further search for a commercial uranium deposit is warranted in the vicinity of this mine. A sample of handpicked radioactive hydrocarbon from the Smuggler mine, San Miguel County, contains 0.29 percent U, and this occurrence may be of importance in interpreting the regional geologic setting of the uraniferous hydrocarbon-bearing vein deposits near Placerville, Colo.

Reconnaissance in the eastern and central San Juan Mountains will be continued during fiscal 1954, to locate possible uranium occurrences and to determine what physical exploration will be desirable in the search for commercial uranium deposits. The reconnaissance is planned to include work in the Bonanza, Beidell, Embargo, Stunner, Gilmore, Platoro, Jasper, Summitville, Creede, and Lake City mining districts. In the laboratory, petrographic and mineralogic work, supplemented by chemical and spectrographic analyses, will be done in the attempt to discover clues useful in the search for uranium deposits.

Western San Juan Mountains, by A. L. Bush

The uranium-vanadium deposits of the Entrada sandstone in the western part of the San Juan Mountains and the adjacent northeastern part of the Colorado Plateau contain large but low-grade reserves of uranium. The

geographic proximity of these deposits to the base and precious metal deposits of the main San Juan igneous province allows for detailed study of their relationships. The work in this area is planned to appraise uranium and vanadium reserves and resources, to determine the continuity of uranium-vanadium deposits between districts, and to investigate the origin, source of the metals, depositional controls, and relationship to the San Juan mineralization mentioned above.

A preliminary resource study was completed during the field season of 1952 (TEM-298). The work was recessed November 1, 1952, and will be resumed about June 1, 1953. During the coming field season, areal geologic mapping of three $7\frac{1}{2}$ -minute quadrangles in the Placerville district will begin. This district contains the largest known resources of uranium and vanadium. The areal mapping will be tied in, to the east, with the geologic mapping of the Telluride mining district. Some detailed mapping in both uranium-vanadium and base-metal deposits probably will also be done.

Boulder batholith, Montana
by G. E. Becraft

The objectives of the Trace Elements studies in the Boulder batholith area are: (1) to determine the distribution and geologic setting of radioactive minerals, (2) to formulate ideas that might lead to the discovery of new sources, and (3) to evaluate the resources of uranium. To accomplish these, the geology of selected areas known to contain deposits of uranium has been mapped, individual deposits of uranium have been mapped in detail, petrologic and mineralogic studies are now in progress, and radiometric traverses have been made.

Petrographic studies of the quartz monzonite of the Clancy Creek area support field evidence that this quartz monzonite may be separated

into four mappable units according to textural and modal differences that are apparent in hand specimens. Two of these units--the common medium-grained, biotite-hornblende quartz monzonite and a porphyritic quartz monzonite that appears to have been permeated before complete crystallization by solutions rich in potash and silica--are of considerable areal extent. Chalcedonic vein zones and anomalous radioactivity are much more numerous in the common quartz monzonite but a few have been detected in the porphyritic quartz monzonite.

Analytical data and detailed studies of the mine workings on properties mentioned in TEI-310 permit computation of some reserves. However, the economic potential and reserves for the entire Boulder batholith area are not yet known.

Analyses of two samples from the Uncle Sam mine in sec. 27, T. 7 N., R. 5 W., indicated a uranium content of 0.069 percent eU - 0.054 percent U and 0.025 percent eU - 0.015 percent U. The first sample was chosen as the most radioactive specimen found on the mine dump and the second was from a small vein that had been stoped for an unknown distance below and to the east of a short drift about 265 feet from the portal of the mine. The radioactivity was detected for only a short distance along the vein.

Analyses of two specimens from the outcrop of a chalcedonic vein zone in sec. 1, T. 8 N., R. 4 W., indicated a uranium content of 0.17 percent eU - 0.14 percent U and 0.15 percent eU - 0.12 percent U. The vein zone, about 8 to 10 feet wide, comprises a few tan to dark-gray chalcedony veinlets in intensely silicified quartz monzonite. Anomalous radioactivity was detected for 400 feet along the vein zone. Two secondary uranium minerals, identified as metatorbernite and uranophane,

were found in the altered quartz monzonite near the western end of the vein zone. The strength of the radioactivity and the results of the two analyses indicate that this chalcedonic vein zone should be considered for exploration.

Field work in the northwestern part of the Jefferson City quadrangle will be resumed in June 1953. The geology of about 75 square miles adjacent to the Clancy Creek area and near the Boulder-Comet area is to be mapped. This area is underlain almost entirely by rocks of the batholith and is known to contain several radioactive base- and precious-metal deposits. Also it is anticipated that radioactive "reefs" of the Clancy type may be found in the northern part of the area. Detailed petrologic studies will be continued that will include studies of distribution of uranium in different types of intrusive rocks, petrologic variations in the batholith and related igneous rocks, and alteration associated with different types of mineral deposits.

Thomas Range, Utah
by F. W. Osterwald

The Thomas Range fluorite district is approximately 50 miles northwest of Delta, Utah, in Tps. 12, 13 N., R. 12 W., Salt Lake principal meridian. The uraniferous fluorite pipes cut Paleozoic dolomites along a ridge known as "Spor's Mountain". The final report on the district, by M. H. Staatz and F. W. Osterwald, will be completed probably by late summer. No further work in the district is planned.

The Paleozoic rocks of the district have been correlated in part with previously known stratigraphic sections by fossil content and lithology. In order to delineate the structure of the district the rocks assigned to

the Middle Silurian were divided into five new formations. The stratigraphic section of Paleozoic rocks is summarized below:

		top covered
Devonian	{ Simonson and Guillmette formations, undivided	350 ft.
		1,122 ft.
Silurian	{ Thursday dolomite Lost Sheep dolomite Harrisite dolomite Bell Hill dolomite Floride dolomite	330 ft.
		125 ft.
		135 ft.
		410 ft.
		235 ft.
Ordovician	{ Fish Haven dolomite Swan Peak formation Garden City formation	190 ft.
		978 ft.
		730 ft.
		base covered

Locally the sedimentary rocks are intruded by plugs of acid igneous rocks, and by masses of intrusive breccia. Large areas around the flanks of Spor's Mountain are underlain by flows, tuffs, and agglomerates. On the basis of microscopic study the volcanic rocks have been subdivided as follows:

Acid igneous rocks	{ rhyolite dellenite dacite
Intermediate igneous rocks	{ trachyandesite augite-andesite
Basic igneous rocks	{ trachybasalt augite-enstatite basalt

Devitrification is evident in many thin-sections, and late introduction of F, K, Al, and Si, as a result of end-stage or fumarolic activity, has been shown by chemical analyses and microscopic work. The tuffs are made up of crystal, lithic, and vitric material, and range in composition from andesite through dacite and dellenite to rhyolite.

The district is cut by hundreds of faults, but all rocks strike north-northeast to northeast and dip 20° to 60° northwest. The tilting is believed

to be closely related to the movements that produced the prominent set of northeast trending antithetic faults. This movement probably was a differential uplift of a block southeast of Spor's Mountain relative to the northwest block. Volcanic rocks and tuffs, similar to those of the Spor's Mountain area, are relatively undisturbed in the main mass of the Thomas Range one mile east.

During the past year, analyses of fluorite have shown lower percent U than those made in other years. This was attributed at first to depth zoning within the fluorite pipes, but is now believed to be the result of secondary enrichment near the surface, for the following reasons:

(1) carnotite is visible in the fluorite only near the surface; (2) samples with highest percent U were taken very near the surface; (3) no relation was found between percent U and percent fluorite in the pipes; (4) some bodies show no change in percent U with depth; these are located in canyons or on steep slopes where erosion is rapid; and (5) pipes with the higher uranium content are generally distributed about the south end of Spor's Mountain, where the topography is more subdued.

A definite decrease in grade below the surface is shown by the Bell Hill, Lucky Louie, Fluorine Queen, Floride, and Lost Sheep south pipe. The Blowout pipe contains nearly the same uranium content at 240 feet depth as it does at the surface. No significant change in percent U with depth was found in the Lost Sheep main pipe, though individual analyses vary greatly. The fluorite at the Bell Hill and Lucky Louie mines contained silica at depth, and the Blowout ore contained much Ca-Mg montmorillonite at depth.

Placerville hydrocarbons, Colorado
by V. R. Wilmarth

The primary objectives of this project are: (1) to study the relation of hydrocarbon, both radioactive and non-radioactive to the base-metal sulfide vein deposits and to the bedded vanadium-uranium-chromium deposits, and (2) to determine the uranium reserves in the vein deposits.

The geology and ore deposits in the part of the Placerville area, San Miguel County, mapped during the 1952 field season, was summarized in TEI-310, (pp. 96-99). During this period a study of the mineralogy of the hydrocarbon veins showed that the first minerals deposited were calcite, barite, and pyrite, followed by the hydrocarbons, and the base-metal sulfide minerals.

The base-metal sulfide vein deposits can be divided into those that contain abundant hydrocarbon and those in which only minor quantities of hydrocarbon were found. The order of deposition of the sulfide minerals in the two types of vein deposits is pyrite, chalcopyrite, bornite, tetrahedrite, galena, and sphalerite. Tetrahedrite contains minor quantities of silver and is the most abundant sulfide mineral. Galena and sphalerite are rarely found in the vein deposits of type No. 2.

Spectrographic and X-ray analyses of the vein gangue minerals-- calcite and barite--were made to determine the distribution of trace elements in these minerals from various parts of the vein deposits. The results indicate that the calcites contain greater quantities of lead, cobalt, nickel, scandium, vanadium, and the rare-earth metals than the barite. In general, lead and copper are present in calcite from the veins in the vicinity of the Robinson property, whereas rare-earth metals and

zirconium are more abundant in the calcite from the veins west of the Weatherly property. The mode of occurrence of these metals in the calcites is not known.

In the Placerville area hydrocarbon is both non-radioactive and radioactive. It occurs in fault zones, as fracture fillings and as disseminations in the sedimentary rocks of the Cutler and Dolores formations. Hydrocarbon as fracture fillings is generally soft, soluble in organic reagents and by spectrographic analysis contains smaller quantities of trace metals than the non-soluble hydrocarbons from the fault zones and disseminations. In general the trace-metal constituents of the hydrocarbons in the Placerville area are more like those found in oil than in coal.

The hydrocarbon as fracture fillings contains as much as 0.078 percent eU, but the hydrocarbon ash contains from 0.034 to 0.33 percent U; the ash content ranges from 0.54 to 17.0 percent. Hydrocarbon from the fault zones and disseminations contains as much as 9 percent U, but in the hydrocarbon ash, the uranium content ranges from 0.64 to 9.8 percent; the ash content ranges from 13 to 30.1 percent.

The common trace-metal constituents in the hydrocarbon from the Placerville area are silver, cobalt, chromium, copper, molybdenum, nickel, lead, vanadium, and yttrium. In general the hydrocarbon ash that is rich in uranium also contains relatively more copper, lead, molybdenum, and yttrium. The trace-metal content in the ash from the fault-zone hydrocarbon is characterized by more lead and molybdenum and less copper than the ash from the disseminated hydrocarbon in the sedimentary rocks. The trace metal constituents are believed to occur in the hydrocarbon as discrete grains of coffinite and as metallo-organic compounds.

Garo, Colorado
by V. R. Wilmarth

The primary objectives of this project are: (1) to determine the horizontal and vertical extent of the uranium-vanadium-copper minerals in the Maroon formation of Permian age at the Shirley May mine, and (2) to study the mineralogy, genesis, and localization of the ore minerals in the deposit.

The Shirley May deposit near Garo, Park County, Colo., is on the northeast flank of the Garo anticline, a local structure probably related to Tertiary deformation. The sedimentary rocks have been broken by several north to northeast-trending faults that have displaced the rocks as much as 1,000 feet horizontally. At the mine, tyuyamunite and carnotite, the principal uranium minerals, are associated with volborthite, calcovolborthite, azurite, malachite, chalcocite, covellite and complex vanadium oxides; they occur as disseminations, as cementing material, and as fracture fillings in three separate medium- to coarse-grained sandstone beds. The gangue minerals are calcite, manganite, and hematite. Most of the 272 tons of ore produced from this deposit were mined from bed No. 1, which is 50 to 150 feet stratigraphically above the other ore-bearing sandstone beds. The average grade of the ore produced is 0.16 percent U and 0.72 percent V_2O_5 . The uranium content of samples from the mine ranges from 0.001 to 0.48 percent U.

The ore from this mine can be classed as: (1) sandstone in which tyuyamunite is the principal ore mineral, and (2) sandstone which contains intermixed uranium, vanadium, and copper minerals. Type No. 1 is found only along faults, is rich in calcium, and contains from 0.001 to 0.5 percent U; type No. 2, the principal ore type, is found in all three sandstone

beds, and varies from hematite-manganite rich sandstone that contains 0.002 percent U to sandstone that has abundant yellow-green vanadium-uranium minerals and contains as much as 4.34 percent V_2O_5 , 0.3 percent U, and 1.34 percent Cu. Distribution of the ore minerals in the sandstone beds is well shown at this deposit. The calcite-rich, well cemented, outer zone of the sandstones contains generally more yellow uranium minerals, whereas the core of the mineralized bed is soft, contains less calcite, and is rich in hematite, manganite and the green to dark-brown vanadium minerals.

The localization of ore at the Garo deposit is controlled principally by faulting and the porosity of the sandstones adjacent to the faults.

Lost Creek, Wyoming
by D. M. Sheridan, J. T. Collier, and C. H. Maxwell

Exploration and field work were completed at the Lost Creek schroekingerite deposits in November 1952 (Sheridan, TEM-518). The major objective of office work during the past six months has been to compile all the geologic and economic data that were accumulated at Lost Creek intermittently during the period 1949-1952. The calculation of reserves and most of the map compilations have been completed.

Two large areas containing schroekingerite deposits were indicated by the exploration. The main mineralized area, at least 10,000 feet long and as much as 1,100 feet wide, occurs within the Cyclone Rim zone of faulting, a structural feature which trends northwest for a distance of 12 to 15 miles. A subsidiary mineralized area, about 8,200 feet long and as much as 600 feet wide, lies north of and sub-parallel to the main area.

The subsidiary area is connected to the main area by sparsely mineralized ground near the western end. The two mineralized areas are on the southwestern limb of a syncline, the axis of which trends northwest. Several major lineaments intersect the Cyclone Rim zone of faulting in the immediate vicinity of the mineralized areas.

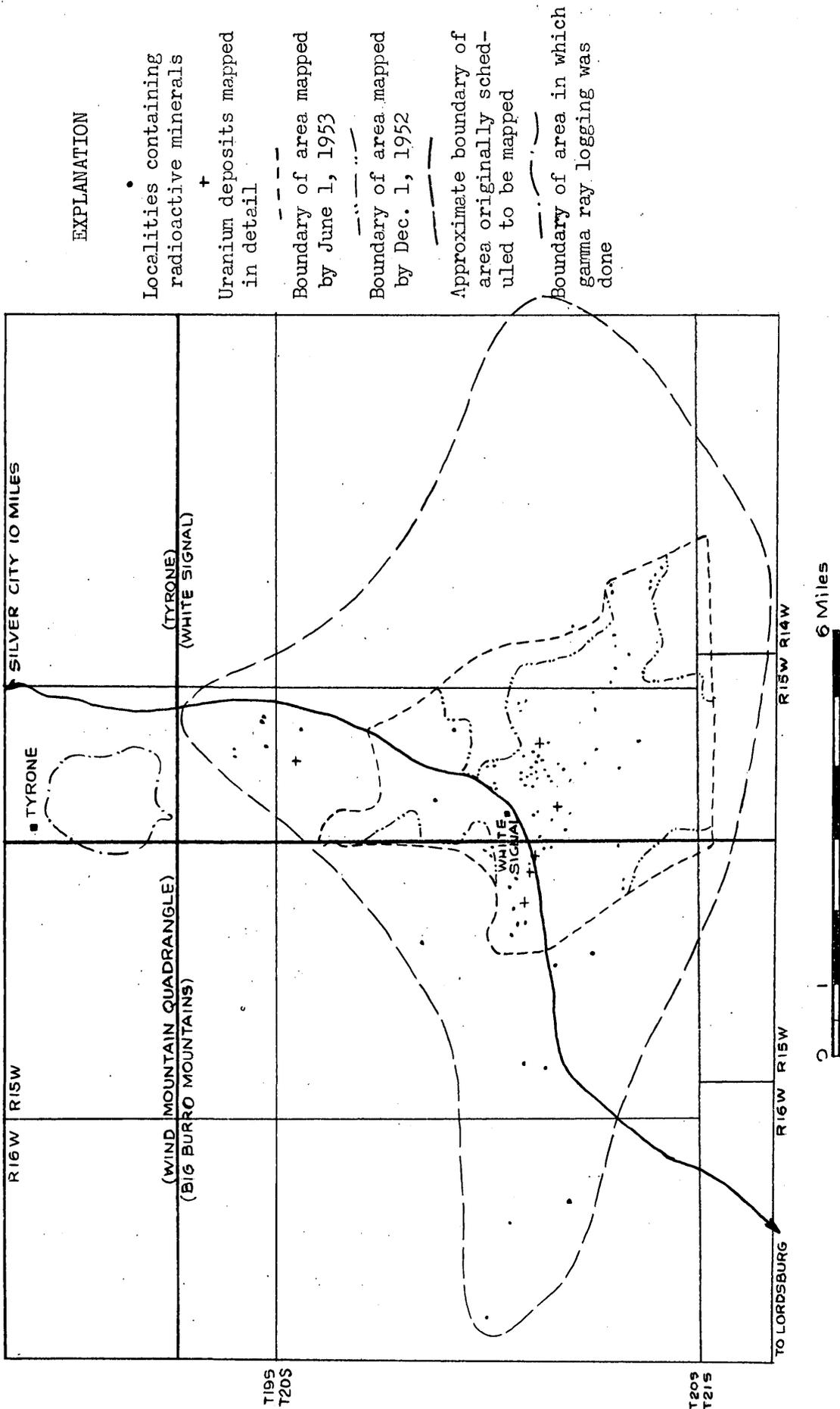
The calculation of grade and tonnage was completely revised according to new data obtained during the past field season. These data supercede the preliminary tabulations reported in TEM-288, by Sheridan, Collier, and Sears. (See TEI-331.)

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

The objectives of the investigations in the White Signal district are: (1) to find minable deposits of uranium, (2) to appraise the uranium resources of the district so that the production "potential" can be established, and (3) to determine the nature and origin of the deposits, not only as a guide in the search for uranium in the White Signal district, but also to aid in other areas. To achieve these objectives a radiometric survey of the district, detailed mapping of individual properties, and regional mapping of about a 60-square-mile area was planned. Results of the radiometric survey, completed last fall, were discussed in TEI-310.

During the past six months regional mapping, at a scale of 1:12,000, was completed of the central and most important part of the White Signal district, an area of about 16 square miles (fig. 5). Three of the most promising deposits were mapped in detail.

A final report of the project is now being written, and will be submitted early in fiscal year 1954. The project will be suspended and no



EXPLANATION

• Localities containing radioactive minerals

+ Uranium deposits mapped in detail

--- Boundary of area mapped by June 1, 1953

- · - · - Boundary of area mapped by Dec. 1, 1952

· · · · · Approximate boundary of area originally scheduled to be mapped

--- Boundary of area in which gamma ray logging was done

FIGURE 5 .---INDEX MAP OF WHITE SIGNAL DISTRICT, GRANT COUNTY, NEW MEXICO

further work is planned in the area for the near future. Although only 16 square miles of the originally scheduled 60 square miles have been mapped, it is felt that inasmuch as they comprise the central and most important part of the uranium-bearing area, little additional pertinent information on the uranium deposits would be obtained by additional mapping.

SEARCH FOR AND GEOLOGY OF URANIUM IN CARBONACEOUS ROCKS

Reconnaissance

Eastern states

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

Field work was conducted during parts of January, February, April and May by S. W. Welch, J. L. Snider and J. C. Ferm. Most of the localities examined were coal mines, either operating or abandoned. Several long stratigraphic sections exposed in road cuts were measured and checked for radioactivity with the scintillation meter. Field work was done in the anthracite fields in eastern Pennsylvania, and in Jefferson and Beaver Counties in western Pennsylvania. Additional field work is planned in June in western Pennsylvania, Alabama and northwestern Georgia.

Channel samples were taken of coal beds of commercial thickness and extent. At most localities, the coal bed was sampled by benches and the samples tested separately to determine if uranium were present in one bench and absent in the rest of the bed. In addition to the sampling, the coals and associated rock were checked for radioactivity with a scintillation meter. Clays and shales which showed greater than normal radioactivity also were sampled. Samples were crushed later in a jaw crusher and their radioactivity measured with a Berkeley scaler equipped with an assay cup. Readings of samples were taken for periods of two or three minutes and compared to readings of standard samples having 0.015 and 0.020 percent eU. Samples were then shipped to the Washington Trace Elements Laboratory for further radiometric analysis. These analyses have not yet been completed.

Samples from 8 of the localities examined have shown radioactivity of potential interest. These are listed below:

<u>Sample No.</u>	<u>Equivalent uranium</u>	<u>Location</u>
200 SWW	0.001	Northumberland County, Pennsylvania. Abandoned strip mine 2.5 miles northwest of Mt. Carmel town limit and 0.4 miles northeast of State Route 54. Lykens No. 2 coal - lower 2 feet.
234 SWW	.001	Schuylkill County, Pennsylvania. Road cut 1.0 mile northeast of Frackville town limit and 0.1 mile southeast of State Route 924. No. 6 coal - upper 3'10"; two samples.
235 SWW	.001	
242 SWW	.001	Schuylkill County, Pennsylvania. Abandoned mine opening 0.2 mile south of Delano. Buck Mountain coal - lower 1 foot.
323 SWW	.001	Carbon County, Pennsylvania. Strip mine 0.4 mile east of road junction at Tresckow and 0.1 mile south of all-weather road. Buck Mountain coal - middle bench 2'4".
11 JLS	.001	Jefferson County, Pennsylvania. Road cut on north side of Worthville. Lower Kittaning coal - lower 1'4".
43 JLS	.005	Beaver County, Pennsylvania. Road cut 1.5 miles southeast of Darlington. Lower Freeport coal - lower 3 inches and upper 2 inches of underclay.
44 JLS	.006	
45 JLS	.010	Beaver County, Pennsylvania. Strip mine at same locality as 43 and 44 JLS. Lower Freeport coal - upper 3 inches of underclay and lower 6 inches of coal.
46 JLS	.006	
54 JLS	.005	Beaver County, Pennsylvania. Road cut 2.0 miles southwest of Darlington. Lower Freeport coal - upper 4 inches of underclay and lower 5 inches of underclay.
55 JLS	.004	

Analyses have been received for samples from Ohio, collected in October 1952. Only two samples of coal showed as much radioactivity as 0.002 percent eU.

<u>Sample No.</u>	<u>Equivalent uranium</u>	<u>Location</u>
90 SWW	0.002, 0.002	Carroll County, Ohio. Abandoned strip pit of James Bros. Coal Company. SW-SE-SW sec. 33, T. 16 N., R. 7 W. Middle Kittanning coal - 3'6" coal.
105 SWW	0.002, 0.003	Belmont County, Ohio. Truck mine of Bradford Coal Company. C-N-SW sec. 25, T. 7 N., R. 3 W. Pittsburgh coal - 5'10" coal with two $\frac{1}{2}$ inch shale partings.

The only occurrences of radioactivity of potential interest are the two localities in Ohio, and the basal few inches of the Lower Freeport coal and its underclay at three localities in Beaver County, Pennsylvania. Further work seems warranted in the vicinity of these localities in the form of detailed sampling and field checking of the coal and associated rock with a scintillation meter in an attempt to determine the type of occurrence and its extent.

In addition to the above localities coal at some localities gives radioactivity readings equivalent to about 0.001 percent U. Chemical analyses for uranium are being made of these samples to check the field radioactivity measurements. Pending the results of these analyses, further work might be warranted in the vicinity of some of these localities.

Western states

New Mexico, by G. O. Bachman, E. H. Baltz, Jr., and R. B. O'Sullivan

Reconnaissance work on coal and black shale in New Mexico during 1952 was largely an extension of work initiated during the 1951 field season. No uranium deposits of economic interest were found, although minor amounts of uranium were noted at several localities. These localities include

Canyon Mulatto, Hosta Butte, Satan Pass, Mariana Pass, and Dalton Pass, McKinley County, New Mexico. The highest percent uranium was found in coaly material from Hosta Butte which contained 0.033 percent in the ash.

A brief reconnaissance study was made of carbonaceous rocks and associated copper minerals in northern Texas and southern Oklahoma but no radioactivity of potential interest was discovered.

Parts of Colorado, Utah, Idaho and Wyoming, by J. D. Wine

Reconnaissance investigations were made for uranium-bearing carbonaceous rocks in 23 areas in Colorado, Utah, Idaho, and Wyoming. Uranium occurs in small quantities in several of the areas examined but no deposits were found that appear to have commercial possibilities.

Uranium-bearing carbonaceous rocks in the Bear River formation of Lower Cretaceous age were found over a widespread area in southeastern Idaho and adjacent parts of Wyoming. Coal in the Bear River formation contains as much as 0.03 percent U in the ash in the Caribou Mountains about 10 miles southwest of the Fall Creek area in Bonneville County, Idaho. Coal in the Bear River formation contains as much as 0.009 percent U in the ash about 10 miles west of Driggs in Teton County, Idaho.

Coaly shale in the Bridger formation of Eocene age contains as much as 0.012 percent U in the ash in southwestern Sweetwater County, Wyo. Seven additional areas were examined in which beds of coal or carbonaceous shale contained more than 0.002 but less than 0.007 percent U in the ash. Fresh bituminous sandstone from the Vernal area, Uintah County, Utah, contains only small quantities of uranium.

Further investigations of these occurrences are not planned at the present time. However, additional reconnaissance of the Bear River formation in Idaho will be made at the first opportunity.

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

In Colorado, the South Park, Crested Butte, Paonia, Trinidad, Colorado Springs, and Canon City coal fields were examined. Coal-bearing rock in the vicinity of Mancos and Durango, Montezuma and La Plata Counties, as well as coal in the Denver Basin, were also examined. Only two samples contained more than 0.002 percent U in the ash. A sample of impure coaly shale in the Belden formation of Pennsylvanian age, 18 miles southeast of Crested Butte, Gunnison County, and a sample of carbonaceous shale in the Laramie formation of Cretaceous age 12 miles north of Fort Collins, Larimer County, each contained 0.006 percent U in the ash.

In Wyoming, the Cambria coal field, Weston County, was examined. A 4.8-foot bed of impure coal contained 0.0085 percent U in the ash. This bed is probably the stratigraphically highest coal in the coal-bearing Lakota sandstone. Other coals, stratigraphically lower, and that were commercially mined in the past do not contain detectable radioactivity.

The reconnaissance in Montana was concentrated in the Ekalaka lignite field, Carter County, and several beds of uraniferous lignite were found in the southern part of the field about 10 miles south of Ekalaka.

The uraniferous lignites occur in the Ludlow member of the Fort Union formation of Paleocene age, which is unconformably overlain by massive tuffaceous sandstones of the Arikaree formation of Miocene age. The lignite beds are lenticular, but it is possible to follow their outcrop for three or more miles and they are thought to have a minimum areal extent of three or more square miles. Before the close of the field season, several sections, were measured and 94 samples of lignite were collected, of which 65 contained 0.005 percent U in the ash, or more. At a locality in the SE $\frac{1}{4}$, sec. 25, T. 1 N., R. 58 E., Carter County, one 8-foot bed of lignite contains an

average of 0.017 percent U in the ash and about 34 percent ash. A 15.5-foot bed about 100 feet above the 8-foot bed contains an average of 0.057 percent U and about 34 percent ash. Other lignite beds, stratigraphically below the 8-foot bed do not contain detectable radioactivity. Analcite is abundant in the uraniferous beds.

Detailed mapping will begin in the 1953 field season. A few exploratory drill holes probably will be necessary to evaluate the potentialities of the area.

California and adjacent states, by G. W. Moore

Coal was examined at most of the localities mentioned in the literature or listed in the files of the California Division of Mines but most contained little uranium. Those coals containing more than 0.003 percent U are discussed below.

The most highly uraniferous material found in this investigation was a bed of lignite in the NE $\frac{1}{4}$, sec. 9, T. 3 N., R. 16 W., south of Newhall in Los Angeles County, California. The lignite is only 6 inches thick but it contains 0.020 percent U, 37.7 percent ash, and 0.054 percent U in the ash. No other coal outcrops were found in the area.

Uranium-bearing lignite also was found in the Lone coal field in Amador County of central California. This material is the only coal being mined at the present time in the state. The lignite from the two operating mines is used as a raw material for the production of montan wax and other industrial chemicals. The richest lignite sampled contained 0.004 percent U, 59.8 percent ash, and 0.007 percent U in the ash. Other samples from the same bed contain as low as 6.68 percent ash so probably the ash of this sample was increased by surface wash. The sample quoted is the upper 9

inches of a 12-foot lignite zone and the uranium content decreases progressively downward through the zone. It is believed that the uranium was introduced to the lignite by solutions which passed through the overlying Valley Springs formation--a unit composed primarily of volcanic ash of rhyolitic composition. To the west of the mines sampled the lignite beds are directly overlain by the Valley Springs formation and though no exposures were found in this portion of the coal field, possibly physical exploration might show that the lignite there is more highly mineralized than that examined. If somewhat greater concentrations of uranium could be found the uranium might be recovered as a byproduct.

At the abandoned Fireflex coal mine (NW $\frac{1}{4}$, sec. 21, T. 17 S., R. 10 E.) north of the Stone Canyon coal field, San Benito County, Calif., the 5-foot coal bed contains less than 0.001 percent U. Nine feet above this bed, however, there is a 6-inch coal bed which contains 0.005 percent U, 25.1 percent ash, and 0.021 percent U in the ash.

Several coal mines were examined in the Corral Hollow coal field, Alameda County, but the only uranium-bearing coal found was in a 10-inch bed in a road-cut in the NW $\frac{1}{4}$, sec. 25, T. 3 S., R. 3 E. It contains 0.003 percent U, 54.4 percent ash, and 0.006 percent U in the ash.

~~No~~ coal containing as much as 0.003 percent U was found in southern Oregon or in western Nevada.

An oil-saturated sandstone collected from a quarry for road material 1 mile south of Edna, San Luis Obispo County, California, contains 0.002 percent U. The sandstone has 90 percent ash so if all the uranium is present in the oil and this material could be leached from the rock the oil would contain 0.02 percent U. A possible further concentration of the uranium could be effected by ashing the leached oil.

No further work is planned on these deposits in California until more promising areas in other states have been investigated. Further field examinations may be made of the Ione lignite and the Edna oil-saturated sandstone by parties engaged in other work in these areas.

Mineralogy and geochemistry of carbonaceous rocks

by I. A. Breger, M. Deul, R. Meyrowitz, and S. Rubinstein

Uraniferous coals

Investigations of the mineralogy and geochemistry of the uraniferous lignite from Harding County, South Dakota, were reported in TEI-284 which appeared in March 1953. It was shown that the uranium is retained by the coal in the form of an organo-uranium compound or complex which is insoluble at pH's above 2.2. The uranium is not associated to any appreciable extent with the minerals of the lignite.

Miscellaneous carbonaceous substances

A coordinated effort is being made to establish the nature and structure of complex organic uraniferous substances other than those which are definitely coals or asphalts. Employing electron microscopy, spectrographic analysis, micro organic ultimate analysis, and determinative X-ray mineralogy, a number of "asphaltic" pellets from the Permian of Oklahoma have already been studied in some detail. These pellets, which were provided by J. W. Hill of the Mineral Deposits Branch, were previously examined microscopically by J. M. Schopf of the Coal Geology Laboratory of the USGS. It is hoped that further work on substances of this nature can be carried out during the coming months, and that it will be possible to report in detail on the structure and composition of these pellets.

Carbon-hydrogen ratios were obtained on a number of samples of uraniumiferous carbonaceous materials obtained from the Colorado Plateau in an effort to chemically establish their asphaltic or coaly character. This work, which is still in progress, has led to the development of a simple field technique for the differentiation of asphalts, coals, and other carbonaceous substances based on solubility and specific gravity. It is hoped that proper interpretation, based on chemical and physical analyses, of the nature and origin of the varied vanadium- and uranium-bearing carbonaceous substances found on the Colorado Plateau will contribute to the determination of the geochemical conditions under which these elements were transported and deposited.

Black shale

by I. A. Breger, M. Deul and S. Rubinstein

Studies on the composition and structure of black shales have been initiated recently in response to requests for a comparative study of solid, stratified carbonaceous material isolated from the Chattanooga shale and of the radioactive Kolm lenses from Sweden.

Appropriate splits have been made of a 250-lb. sample of Chattanooga shale representative of 5 tons of the material sent to Battelle Institute in 1949. Following careful crushing, grinding, and sieving operations, the -325 mesh fraction has been further fractionated in an air elutriation system for the collection of subsieve sizes. Selected fractions are now being analyzed. It is hoped that the shale may be separated into organic and inorganic concentrates and that further study of these fractions may make it possible to establish the structure of the organic material and its relationship to the uranium in the shale.

District studies

Dakota region
by J. R. Gill

On October 1, 1952, a 10,000 foot diamond core drilling program for uraniferous lignite was begun in the Mendenhall area, Harding County, South Dakota, by the Mining Division, Region V, Bureau of Mines. A total of 38 holes were scheduled for drilling, and 29 holes have been completed. A total of 6,910 feet was drilled in a period of eight months. The nine remaining holes are expected to be completed by July 15, 1953.

Considerable difficulty has been experienced in recovering core from the uraniferous lignite-bearing Ludlow formation. Core recovery in non-coal rocks is about 60 percent and recovery of the mineralized lignite beds is about 80 percent.

Analyses of samples from 10 of the 29 holes drilled thus far show that the upper mineralized bed exceeds 5.5 feet in thickness and the uranium content of the ash ranges from 0.018 to 0.030 percent. In a few holes the upper foot or so of lignite contains as much as 0.35 percent U in the ash.

In addition to the drilling program, the Bureau of Mines collected five-ton bulk samples of lignite from five localities within the Mendenhall area. The uranium content of the ash for these samples ranged from 0.027 to 0.053 percent.

Upon completion of the current drilling program and analysis of samples, a report will be prepared to include estimates of reserves of uraniferous lignite in the Mendenhall area.

Uranium minerals in Cedar Canyon, Harding County, South Dakota, by J. R. Gill

During the geologic investigations supplemental to the drilling program in the Mendenhall area, Slim Buttes, Harding County, S. D., a small deposit of a yellow uranium mineral similar to carnotite was discovered. The deposit is in channel sandstone at the top of the White River formation of Oligocene age and is at the head of Cedar Canyon, NE $\frac{1}{4}$, sec. 8, T. 16 N., R. 8 E., Slim Buttes, Harding County, S. D., within the Custer National Forest.

The channel sandstones containing the uranium mineral are very fine-grained, poorly to moderately indurated, and contain sparse carbonaceous remains of roots or stems. Numerous thin lenticular sandstones that range in thickness from 0.7 foot to more than eight feet are exposed for about 250 feet along the outcrop with uranium minerals visible for at least 134 feet along this outcrop. The thickness of the uranium-bearing rock ranges from two to more than six feet, with the mineral being most abundant in the sandstone in the lowest part of the channel. The yellow uranium mineral is concentrated near fossil roots or stems and on the surface of the rock along fracture planes. Lesser amounts of the mineral permeate the sandstones. About 30 feet of tuffaceous sandstone of the Arikaree formation of Miocene (?) age overlie this deposit.

The mineralized channel sandstones are at the base of the perched water table that exists throughout the Slim Buttes, and water from the nearby Summit Spring contains 51 parts per billion of uranium. The base of this perched water table is controlled by impervious bentonitic clays at the top of the White River formation. The water that issues from springs at this horizon has passed downward through the tuffaceous sediments of the Arikaree formation. The Arikaree formation is postulated to be the source of the

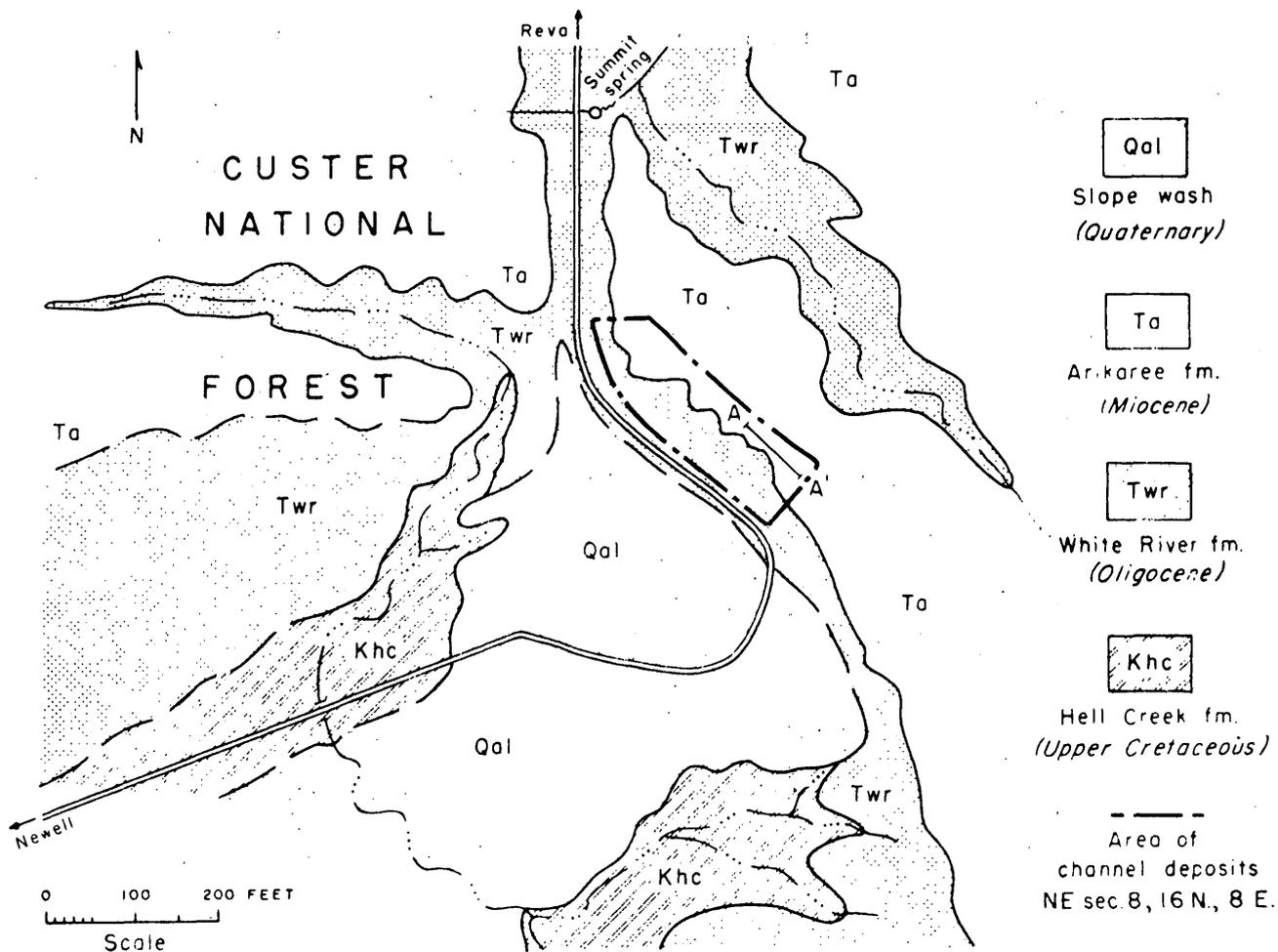
uranium and downward and laterally moving ground water the transporting medium. The sparse carbonaceous remains are thought to cause the chemical or physical reactions responsible for uranium deposition at this locality.

A sketch map and cross section of this deposit are shown in figure 6. The only analyses of samples available are of two grab samples of the carnotite-bearing tuffaceous sandstone; the samples contained 0.08 and 0.23 percent U, respectively. A detailed geologic map is now in preparation. A few core holes less than 50 feet deep will be necessary to determine the underground extent of this deposit.

Coal petrographic studies on Dakota lignite, by J. M. Schopf, R. J. Gray and J. C. Warman

Review of reserve materials from exploratory drilling, which was undertaken by the Survey in the Slim Buttes area, South Dakota, in 1951 and 1952, for uraniumiferous lignite led to the selection of material from four holes as most suited to petrographic investigations. The purpose of this study is to determine the association and correlation of uranium with the organic constituents of the coal. Petrographic coal studies also serve to define one of the three important variables of coal (Type, as distinguished from Grade and Rank) which may be significant in technologic utilization of the coal.

Locations of the four core holes, Nos. 3, 16, 17 and 18, from which more or less adequate reserve samples were available, is shown on the sketch map (fig. 7). Some correlative studies also were undertaken on weathered coal available from the abandoned Mendenhall strip mine, also located in figure 7. Holes 16, 17 and 18 all are deeper than 300 feet; hole 3 reached the coal at a little more than 88 feet. At this shallower depth the upper coal bed showed some signs of weathering.



GEOLOGIC SKETCH MAP OF CEDAR CANYON CARNOTITE DEPOSIT, SLIM BUTTES, HARDING COUNTY, SOUTH DAKOTA

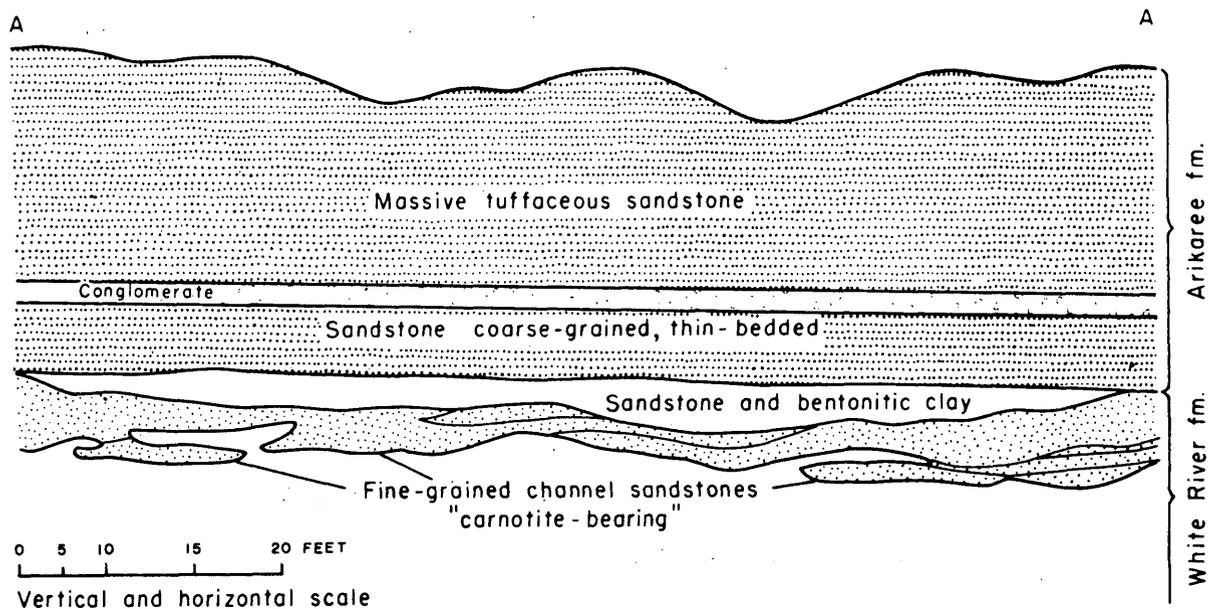


Fig. 6—Cross section A-A'.

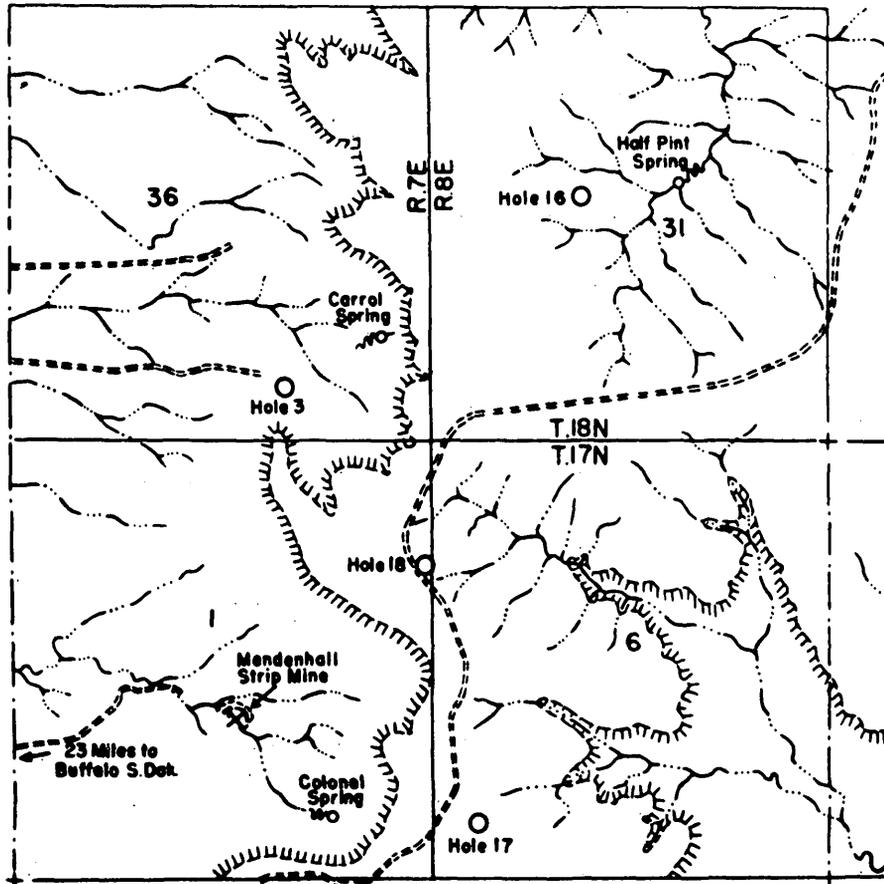


Fig. 7—Sketch map of part of U.S.G.S., Slim Buttes Exploration Area.

The uppermost (Mendenhall) coal bed in all four core holes shows a marked top-preferential distribution of radioactivity. Uranium determinations have been made on all coal samples and are generally consistent with the radiometric values, expressed as pulses per minute per gram (P/M/G), that are shown in figures 8-11. However, P/M/G determinations were obtained for both coal and non-coaly strata and, in a number of instances, were obtained from shorter intervals of core thickness than seemed justified in sampling for the more costly chemical determinations. The relative significance of these P/M/G values seems satisfactory and generally will approximate the parts per million of uranium, chemically determined, if multiplied by a factor of from fifteen to twenty times. The considerable variation in prominence and location of subordinate peaks of radioactivity also seems to be supported by the analytic data but the actual accuracy of radiometric determinations at lower levels of activity (less than .5 P/M/G), probably is not so good. However, the lower values seem to exhibit considerable relative consistency. The irregularities and differences between the radiometric profiles of the four drill holes evidently are real.

The P/M/G profiles have been used as a guide in planning more detailed petrographic study of the coals. These studies are incomplete and cannot be reported at this time. One objective has been to define the "occurrence unit" of uranium in the coal. The P/M/G profiles show that in samples of a foot or greater thickness substantial undetected irregularities of uranium concentration may occur.

The amount of core material available for study, and the nature of the instrument used, require the study of samples thicker than about $2\frac{1}{2}$ mm. (1/10 inch) by radiometric methods, using a well-shielded end-window type

SUMMARY P/M/G RESULTS, HOLE 3 SLIM BUTTES AREA, HARDING CO., SOUTH DAKOTA

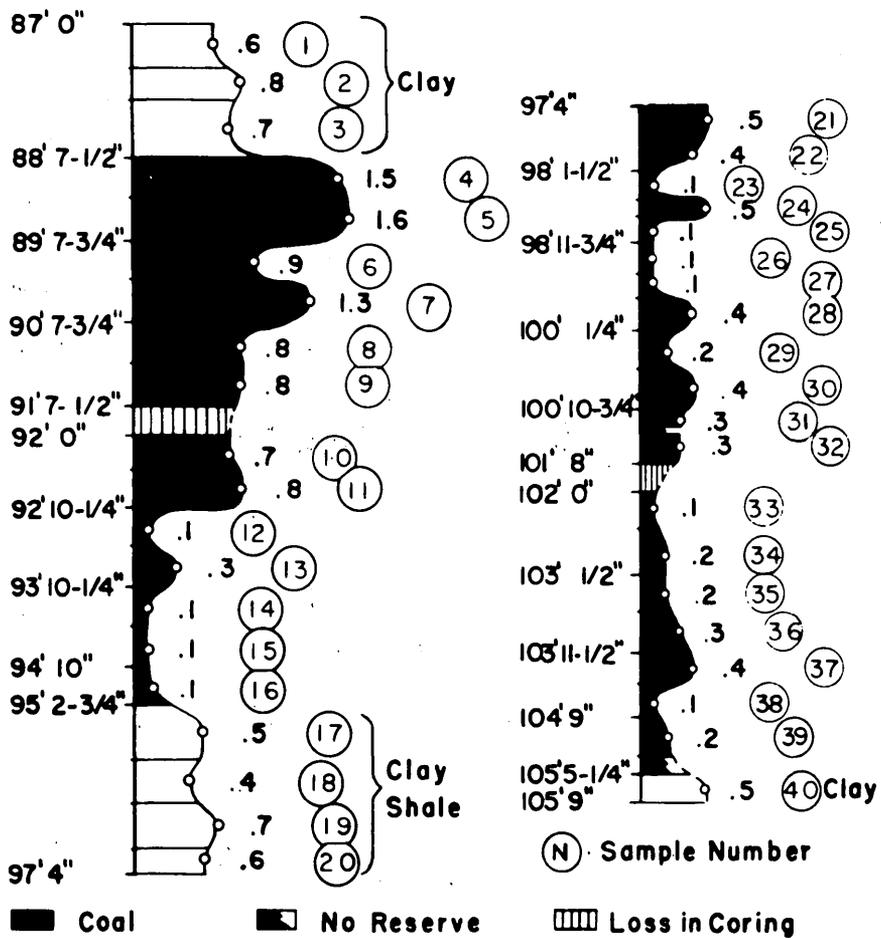


Fig. 8

SUMMARY P/M/G RESULTS, HOLE 16
SLIM BUTTES AREA, HARDING CO., S.D.

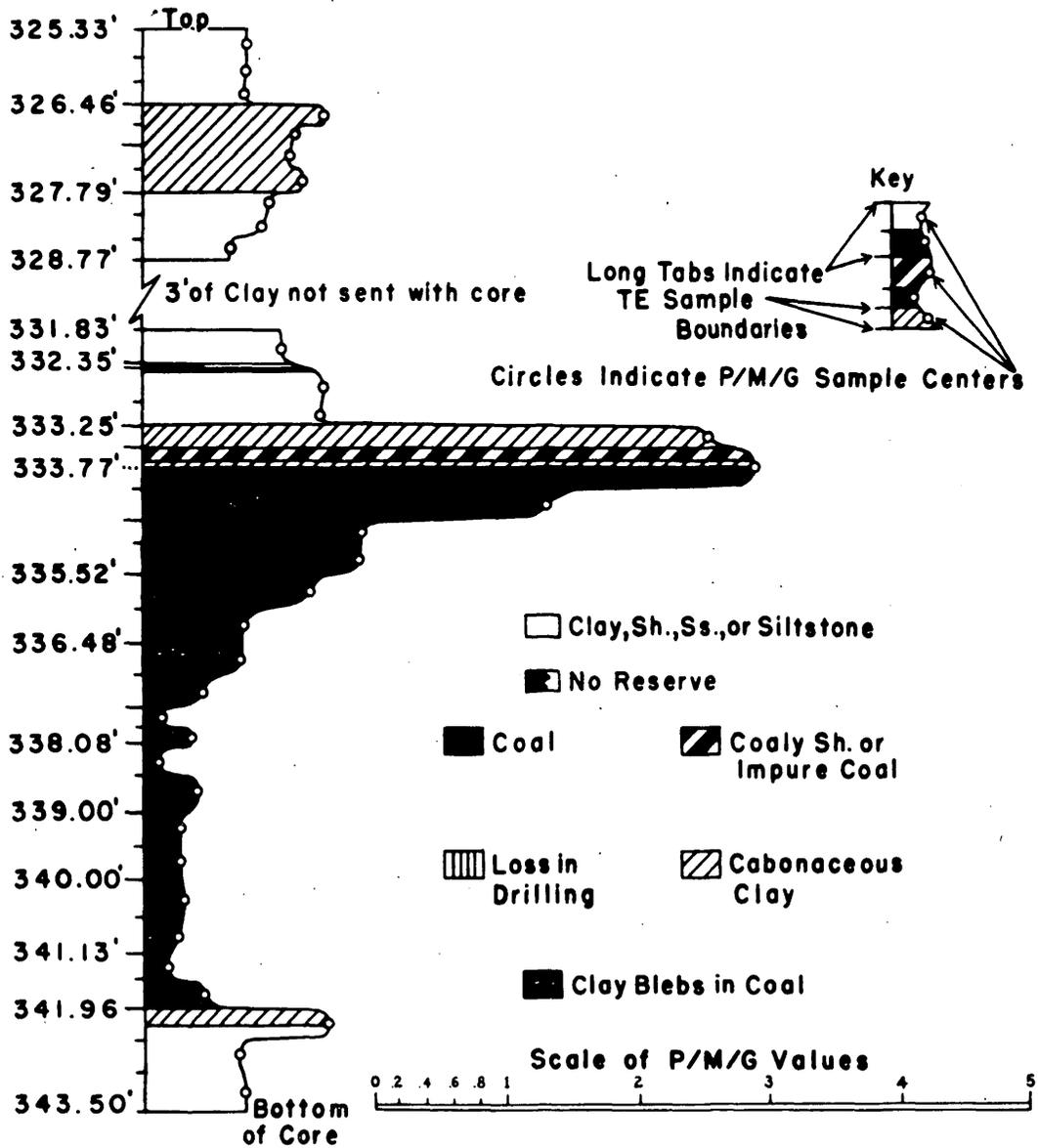


Fig. 9

SUMMARY P/M/G RESULTS, HOLE 17 SLIM BUTTES AREA, HARDING CO, SOUTH DAKOTA

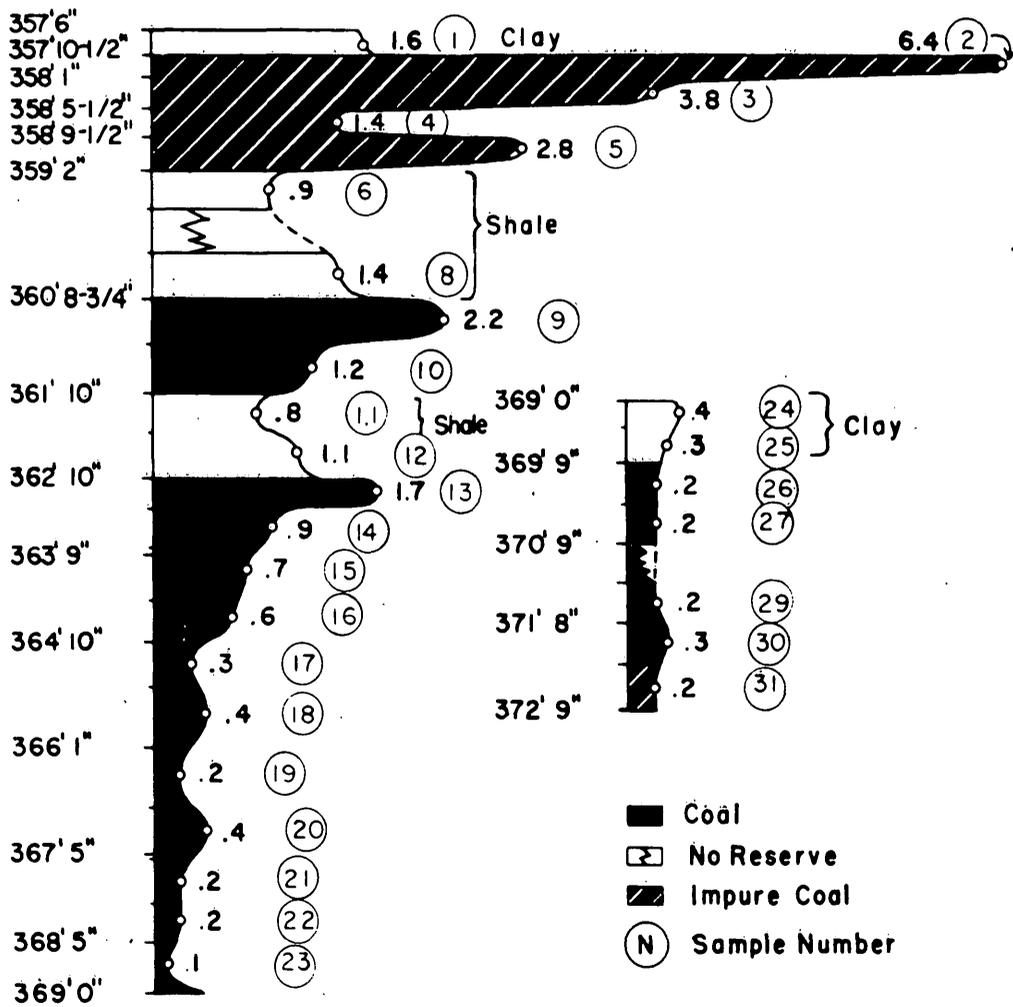


Fig. 10

SUMMARY P/M/G RESULTS, HOLE 18
SLIM BUTTES AREA, HARDING CO., S.D.

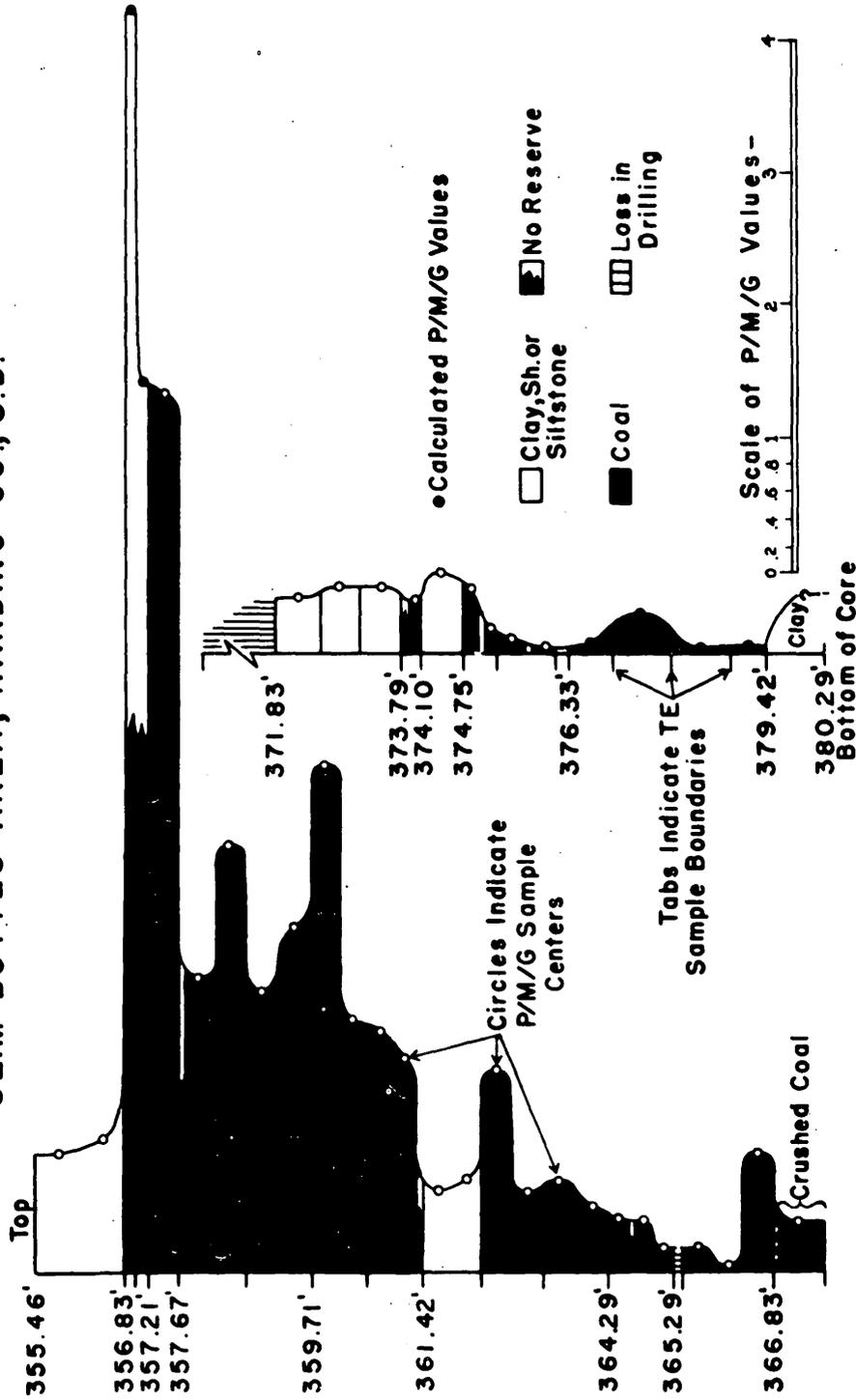


Fig. 11

of Geiger Counter (Victoreen 1867/VG-10A Thyrode tube with 2.3 mg/cm² mica window). Some abrupt variations in radioactivity appear between some of the adjacent 2 mm and 3 mm thick samples, but more commonly gradational values are encountered to suggest that minor trends of distribution range through thicknesses of coal greater than half an inch.

Ninety-one such samples have been prepared from reserve portions of the more radioactive upper part of Hole 3; 149 samples from the upper portion of reserve core from Hole 16 and 130 samples from Hole 18. Samples from Hole 3 have been submitted for ash and for fluorimetric determination of uranium to the Trace Elements Washington Laboratory; P/M/G readings for samples from the other holes are in process of being rechecked for accuracy by ordinary radiometric methods in a shielded counter. Significant determinations require a long period of run and a background count of somewhat comparable duration to attain a probable error of 15 percent on samples of low activity.

The samples from Hole 18 should prove of considerable interest from the standpoint of correlation with organic composition of the coal. Twenty-two thin sections were prepared from the core reserve material and the "heel blocks", remaining after thin sections were obtained, have been carefully split and crushed, after drying, to provide pulverized samples accurately correlated with the adjacent coal of the thin section and most appropriate for detailed microscopic study.

Both microscopy and radiometry for this series from Hole 18 are not far enough advanced to suggest what results may be obtained. The same plan of operation also may be utilized for coal from Hole 17, from which about 18 thin sections have already been prepared.

Both series of thin sections also are applicable to standard types of coal petrographic reporting that reflect the type-composition properties of coal, significant in utilization. These interrupted series of sections are most suitable for study by the layer-sampling method. By this method an accuracy can be obtained that is proportional to the relative amount of attrital coal that is examined microscopically. Thus with a few sections the layer-sampling method may yield only a relatively semi-quantitative indication of the layer-by-layer variations. The accuracy increases with the increase in number of sections used to sample the coal. Studies now planned for superior material presently available in reserve from recent core holes SD-10 and SD-19, in the Slim Buttes area, include virtually complete thin section coverage.

Essentially, the layer-sampling method consists of utilizing megascopic transects for quantitative estimates of pre-vitrain (woody lenses and streaks) megascopic fusain, partings and evident impurities. The scattered thin sections are used to sample and determine the nature of attrital coal in which megascopic entities are dispersed. Both megascopic and microscopic determinations are combined in computing the petrographic composition of all the more or less distinctive layers of coal. Microscopic composition of attrital coal in each layer is determined by relating the quantities of microconstituents in attrital coal actually sectioned to the thickness of the layer and to the known amounts of megascopic ingredients that also are present. A layer-by-layer profile of the coal bed that can be presented by this method is most instructive but the layer results also can be averaged, in proportion to their thickness, to give the average composition of the bed as a whole.

For microscopic determinations the constituents utilized by Thiessen and his coworkers at the Bureau of Mines seem most suitable. However, since much of the anthraxylon (an-thra-xy'-lon) consists of megascopic woody bands, two fractions of this constituent are recognized--bands and lenses of megascopic sizes (thicker than $\frac{1}{2}$ millimeter or 1/50th of an inch) may be classed as pre-vitrain, since these are the (megascopic) vitrain equivalents of higher rank coal. Thinner anthraxylous strands represent attrital constituents that have to be estimated by microscopic measurement. Standards of anthraxylon determination established by Thiessen and long utilized by him and his coworkers exclude from the anthraxylon fraction of coal any materials in shards or strands of material less than 14μ in vertical thickness, even though the smaller fragments, as judged from other criteria, are similar. To this extent anthraxylon also has a micro-textural connotation and is used in this report in that sense.

In addition to translucent humic matter which, except for its high degree of micro-degradation is similar to anthraxylon, translucent attritus, in the sense Thiessen used it, also includes translucent waxes and resins and spore or pollen coats and cuticles. Opaque attritus may be represented by three somewhat different types of components--granular opaque matter, amorphous opaque matter and shards of fusinized material too tiny to be systematically determined with fusain in practical petrographic procedure. As may be inferred by its very different composition, opaque attritus has a vastly differing significance from translucent attritus for coal utilization purposes.

Fusain when observed megascopically is a charcoal-like material. It can be measured megascopically, like pre-vitrain, down to a thickness of about half a millimeter. Smaller fusain particles are also dispersed in a

complete range of sizes in attrital coal and were counted as fusain by Thiessen when they exceeded a thickness of about 40μ . This microscopically determined portion of the fusain fraction of a coal can best be distinguished as attrital fusain. Both megascopic and attrital fusain have similar chemical properties but the size distinction has importance in relation to the physical properties of coal; a plane covered by unmineralized megascopic fusain splits readily and is subject to much degradation in handling whereas fusain dispersed in attrital sizes is retained in the coal to a much greater extent. Thicker layers of fusain may, on occasion, also be relatively impure because their great porosity, inherited from the uncompressed cellular tissues of original plant materials, forms a natural site for the deposit of secondary mineral matter.

A chart showing petrographic composition of the Mendenhall coal bed in Hole 16 is presented in figure 12. A profile of ash and uranium content, as chemically determined, also is presented in correlation with the petrographic layers. The uranium profile has been rounded for better comparison with the P/M/G profile, based on about twice as many sample divisions, that has previously been given as figure 9.

Study of this chart reveals some interesting relationships. Wood material dominates the lower portion of the bed--a relatively small amount of attrital anthraxylon is present. Translucent attritus also is present in relatively small quantity. It is most unusual for a bed of lignite to include as much as 25 percent of opaque attritus; the fusain content, while not exceptional for Paleozoic bituminous coal, is also relatively abundant with regard to the usual composition of lignite. No specific correlation exists between uranium content and these standard coal petrographic constituents. Although the upper layers seem to show a direct relationship between

MENDENHALL COAL BED HOLE 16

Slim Buttes Area, South Dakota

Uranium and Ash Content

Petrographic Composition

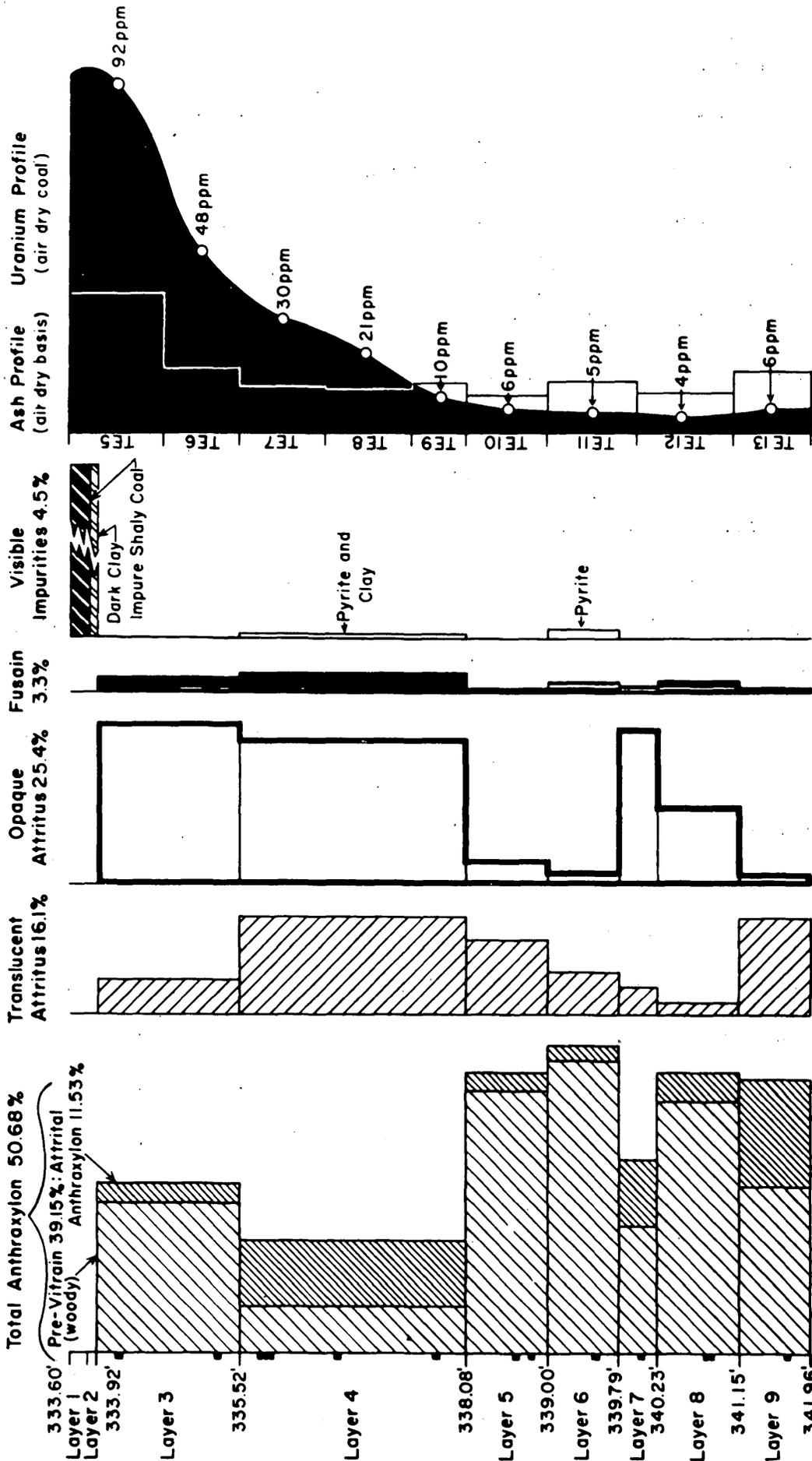


Table Indicate Positions of Thin Sections Sampling Attrital Coal. 15.3% of Attrital Coal is Represented in Sections.

Fig. 12

ash content and uranium this does not hold for other layers of this coal bed and other studies have shown that a truly dependent relationship between ash and uranium content in the Mendenhall coal is highly improbable. The apparent ash-uranium relationship in samples TE5 and TE6 is more likely to be only coincidental. Our other studies have strongly suggested that neither ash nor uranium is actually present in such smoothly "rounded" distribution. The profile of actual occurrence for both materials probably would present an extremely ragged and unrelated saw-tooth outline, in comparison with bulk average values that these samples represent.

A possibly significant, but tentative, conclusion may be suggested regarding utilization of lignite of this character. It is not as likely to produce on charring or destructive distillation as large a tar or oil yield as lignite containing a greater proportion of translucent attritus rich in various types of waxes and resins. Batch hydrogenation tests performed at the Bureau of Mines suggest that most of the fusain accumulates as residue by this method of treatment and that nearly half of the amount usually identified as opaque attritus is similarly non-reactive under these conditions. Translucent components may liquify nearly completely. Normally one would consider the presence of so much of these constituents adverse to hydrogenation possibilities. The presence of uranium could conceivably alter this if it should prove possible to concentrate uranium in a hydrogenation residue along with one of the opaque components.

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

This period was devoted to the compilation of data gathered since 1951 on the occurrence and distribution of uranium in carbonaceous shale and lignite in the Tertiary rocks of the Goose Creek District (see fig. 13). A

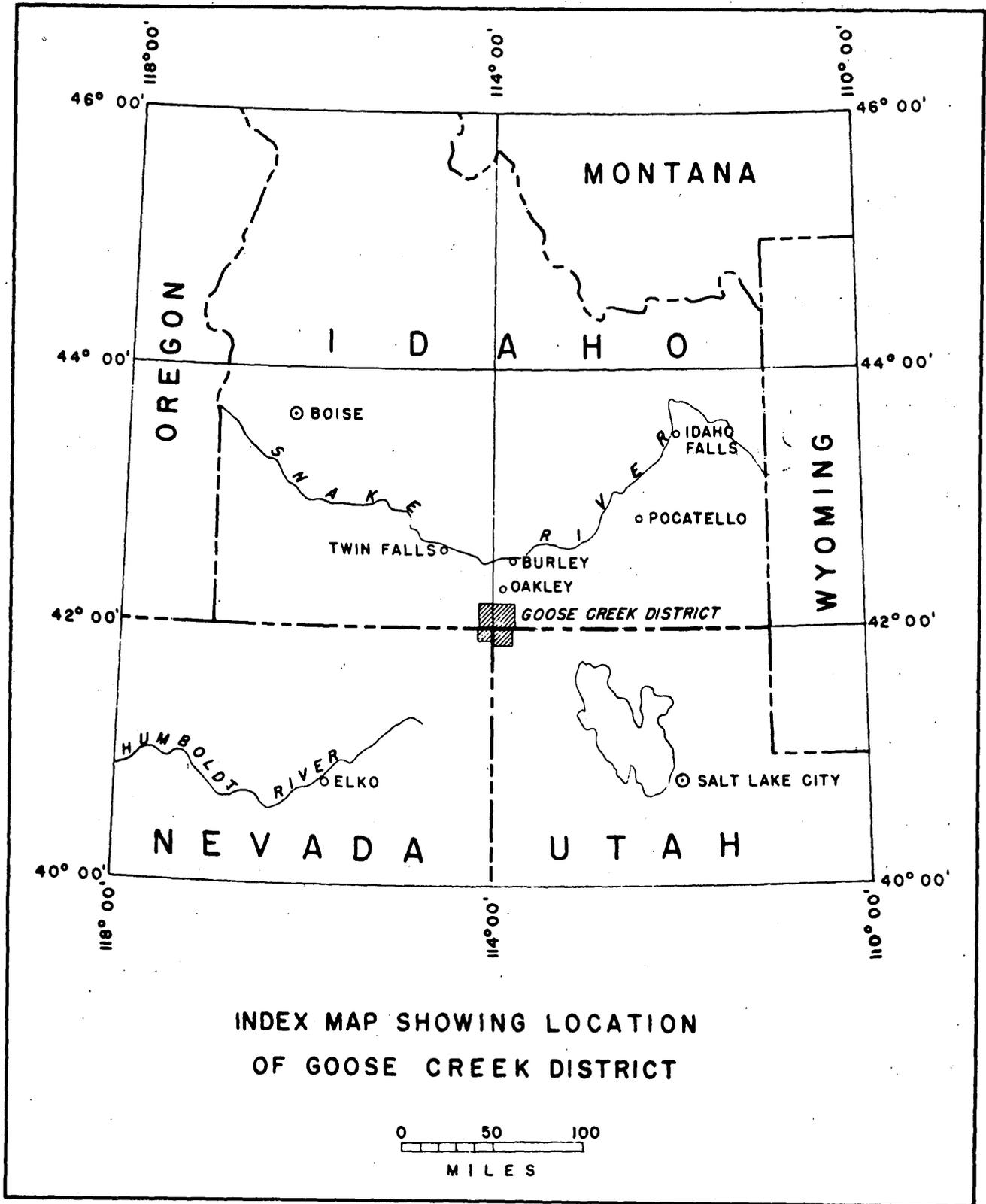


Fig. 13

report is being prepared on the geology and uranium deposits of the district.

The richest known occurrence of uranium in the district is the top foot of an 8-foot bed of carbonaceous shale. The top foot contains as much as 0.12 percent uranium. Beds of carbonaceous shale 1-foot thick or more contain 0.01 percent or more U at 18 additional localities.

About 1,200 feet of core drilling is planned in the Goose Creek district during the 1953 field season with the objectives of (1) testing the principal mineralized zone underground in the area thought to be most favorable geologically, (2) testing stratigraphically lower zones of carbonaceous shale beneath the most uraniferous shales exposed at the surface, and (3) obtaining fresh samples of carbonaceous shale for comparison of the distribution of uranium in fresh and weathered material.

Red Desert area, Sweetwater County, Wyoming
by H. Masursky

A report on the results of exploratory core drilling for uranium-bearing coal in the northern part of the Red Desert area, Sweetwater County, Wyoming, is in preparation. The data from the drilling emphasize the importance of the geologic guides in physical exploration. Two features are notable: first, the area of maximum coal deposition was the Eocene swamp which lay between the Wasatch stream-deposited sandstone on the northeast and the Green River shale which was deposited in lakes to the southwest (fig. 14). Second, the subsequent uranium mineralization of the coal was related to the permeability of the sandstone beds adjacent to the coal. The most favorable area for coal lies in the central part of the zone of coal deposition where the coals are thickest. Since the uranium content is greater to the east, however, the most favorable area for uranium is the eastern part of this coal zone.

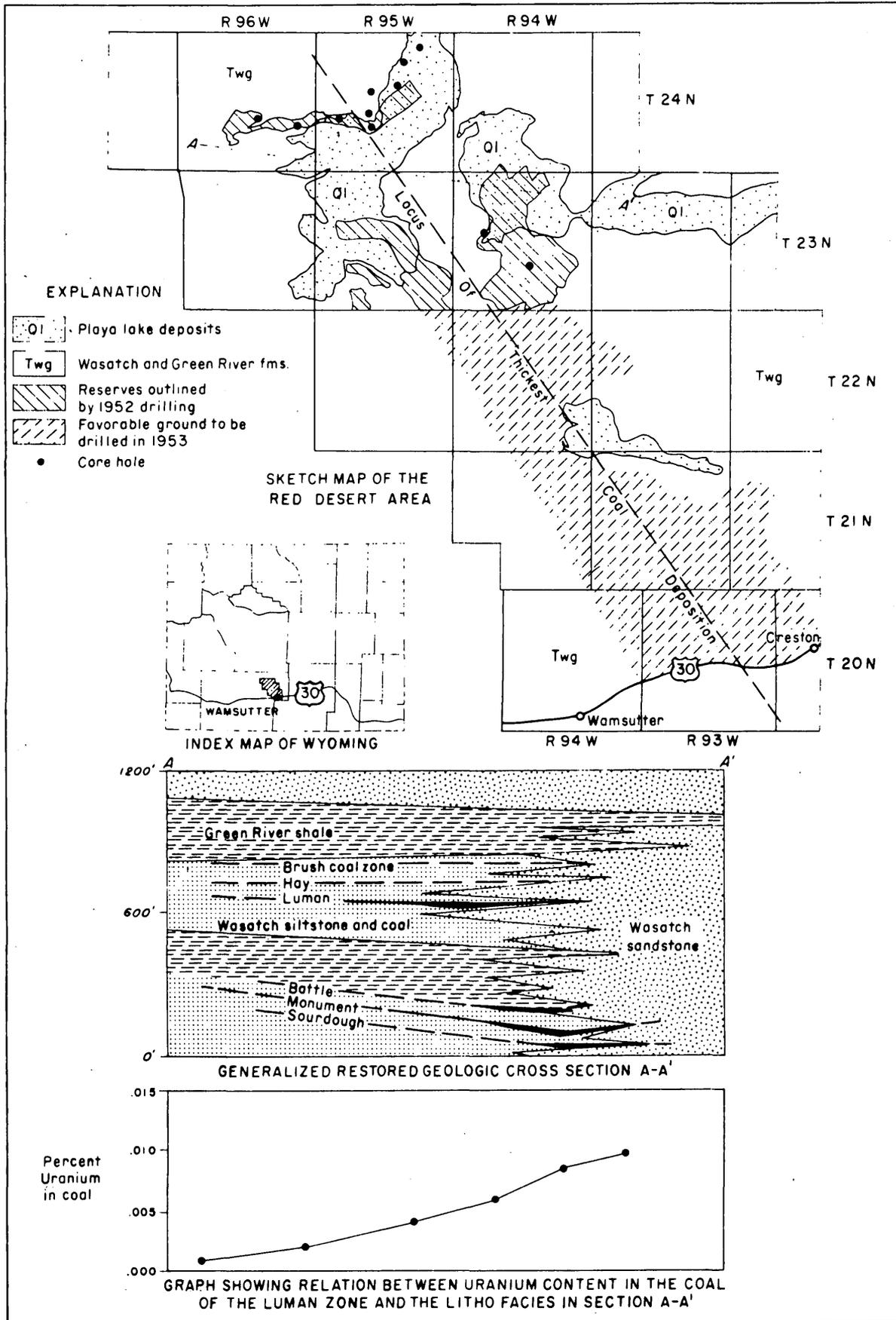


Fig. 14—Sketch map showing results of exploratory core drilling in 1952 and area to be tested by drilling in 1953, Red Desert Area, Sweetwater County, Wyoming.

About 8,000 feet of core drilling is planned for fiscal year 1954 to outline reserves in the favorable area extending 20 miles southward from the area drilled in fiscal year 1953 to U. S. Highway 30. Both reconnaissance and detailed geologic mapping will also be done in the area west of that shown in figure 8. A search will be made for other uraniferous coals in the zone of interfingering between the Wasatch and Green River formations.

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

Geologic mapping in the Fall Creek area, Bonneville County, Idaho, during the 1952 field season provided new data on the extent of the deposit and increased the inferred reserves of uranium. Within this area the Bear River formation of Lower Cretaceous age is repeated at the surface by folding and faulting about 12 times. Uranium-bearing carbonaceous rocks in the Bear River formation were found at several localities in addition to the Fall Creek coal prospect. However, natural exposures of the zone of uranium-bearing rocks are limited to a few outcrops of the carbonaceous limestone bed that overlies the zone of uraniferous coaly shale. Evidence that the zone is uraniferous throughout much of the area mapped consists chiefly of the fact that increased radioactivity is nearly always detected in crossing the soil cover that conceals the zone. In addition, soil samples collected from this zone are uraniferous.

Core drilling will begin in June 1952. The drilling is planned to obtain additional information on the thickness, grade, and areal extent of the uraniferous zone and to test the possibilities of finding higher grade material.

A detailed report on the Fall Creek area is in preparation and will be completed when the results of core drilling are available. Plans for future work will be made if results of the core drilling indicate that additional work is warranted.

Coyote mining district
by H. D. Zeller and E. H. Baltz, Jr.

Uranium-bearing copper deposits in steeply dipping beds of the Sangre de Cristo formation of Pennsylvanian and Permian ages were mapped in the Coyote Mining District, Mora County, N. Mex. The copper and uranium occur in lenticular carbonaceous zones in shale and arkosic sandstone. Samples of weathered material from these zones contain as much as 0.067 percent U and average about 3 percent copper. Metatyuyamunite is disseminated in some of the arkosic sandstone beds and uraninite was identified in some of the copper sulfide nodules in the shale.

The preliminary results of this work are incorporated in TEM-556, transmitted to AEC May 15, 1953. A more complete report is in preparation.

Mapping on a scale of 1:1200 of small areas around the individual deposits will begin in the 1953 field season. A number of trenches will be dug to obtain fresh samples and to determine if both the uranium and copper content increases at depth.

Miller Hill area
by J. D. Vine

Thin beds of algal limestone contain a little more than 0.1 percent U in the Miller Hill area, Carbon County, Wyo. TEI-315, "Preliminary report on uranium deposits in the Miller Hill area, Carbon County, Wyoming" by

J. D. Love was transmitted to AEC April 20, 1953. Field work is planned to begin in June 1953. Airborne radiometric surveys, previously scheduled as the initial phase of field work, cannot be undertaken until the present high level of atmospheric radioactivity resulting from the atomic bomb tests in Nevada has decreased. However, detailed geologic mapping and regional stratigraphic studies of the Browns Park and other formations has begun. Physical exploration to sample promising areas will be planned as soon as geologic studies can provide a sound basis for the drilling.

Black shale investigations

Reconnaissance

TEM-444, "Results of reconnaissance for uranium in nonmarine carbonaceous rocks in parts of California, Idaho, Nevada, Oregon, Utah, and Washington during 1951 and 1952," by Donald C. Duncan was transmitted to AEC June 5, 1953. The report contains analyses of samples of nonmarine carbonaceous rocks ranging in age from Carboniferous to Quaternary and from about 30 localities. Most of the samples contained essentially no uranium, but samples of a thin carbonaceous shale near Hagerman, Idaho, and a small peat deposit in Davis County, Utah, contained more than 0.003 percent U. A report on results of reconnaissance in marine carbonaceous shale is being prepared. Thin beds of marine shale in several formations contain as much as 0.005 percent U in surface samples but none of these shales at localities now known appear to offer much promise. However, shale zones about a foot thick in the Hartville formation penetrated by wells drilled for oil and gas in eastern Wyoming and western Nebraska contain as much as 0.011 percent U. The surface outcrops examined in the Hartville uplift did not

contain uraniferous shales such as are found in the Hartville formation in the subsurface. However, in the reconnaissance, uraniferous copper minerals were found at 19 of the 25 localities examined at the base of the Guernsey formation of Mississippian age and along the upper surface of the underlying Whalen group of pre-Cambrian age. Samples from seven localities contained as much as 0.031 percent U. No deposits of commercial importance were discovered but the widespread occurrence of radioactive copper minerals suggests that a more detailed examination of the area would be desirable.

A review of possibilities of finding uranium in black shales in equivalent or higher grades than in the Chattanooga is being undertaken. Literature on a number of black shales is being collected and studied. From this preliminary survey, black shales on which considerable information is available as to distribution, thickness, and geologic setting, and which are known to be uraniferous in at least some parts of their extent, will be chosen for more detailed study. Samples can then be collected to test the uranium content of geologic features such as areas of thin shale, or areas of overlap on older formations, or areas near the source of sediments. When this information is synthesized, it not only may point to areas where deposits containing uranium in commercial amounts may be found but also it will contribute to an understanding of the geologic controls that affect the origin and distribution of uranium in black shales.

Chattanooga shale investigations
by L. C. Conant

During the current developmental drilling program by the Bureau of Mines, the Geological Survey has assisted in planning hole sites and in selecting the sites on the ground, predicted depths to the shale, and helped

collect the cores of the shale. The cores have then been sawed longitudinally into quarters, logged, and one quarter broken into 1-foot sample units and sent to the Survey's Trace Elements Laboratory for uranium determinations. Other quarters have been variously delivered to the University of Tennessee, to James Schopf of the U. S. Geological Survey for paleobotanical studies, to T. F. Bates of Pennsylvania State College, and to the Bureau of Mines for storage at Mt. Weather. By the end of May about 25 of the 36 designated holes had been completely drilled, and most of the cores had been submitted to the Survey laboratory. Present indications are that most or all of the holes will be finished by June 30.

All the recent analyses suggest that for a north-south airline distance of about 60 miles along the Eastern Highland Rim, there is no great difference in uranium content.

Conant and Rowe (TEM-649) submitted recommendations for a further drilling program designed to find areas where the uranium content of the shale may be somewhat higher than in the Block 1 area. It is also proposed that, if such drilling is carried on, the Survey will do some geologic mapping in areas of most promise in order to supply information on structure, and depth of overburden. A considerable number of sidewall samples will be taken from the projected experimental mine to study the continuity or variations in the uranium content of the shale, both horizontally and vertically.

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

Quarter cores of three holes from the current drilling program in the Youngs Bend area in Tennessee are being made available for study with likelihood that two more may be made available later.

An item of basic interest with regard to the black shale concerns the nature of its laminae and the period of their deposition. Two of the portions of cores now available have provided material suitable for determining whether a correlation between laminae exists for a distance of half a mile. The most highly organic laminae just above the bentonite layer, and others from the base of the "Upper Black" beds, have been traced on transparent plastic by means of microscopic observation. No periodicity of thick or thin bands has been noted and variation in the persistence of microlaminae can be demonstrated in individual core specimens.

The general relation other investigators have reported between organic content and radioactivity suggest an additional possible means of determining whether a similar relation exists within the laminae. The specimens previously studied have been covered with nuclear-type autoradiographic film to determine (1) whether radioactivity is distributed in accordance with the evident lamination and (2) to determine whether any pattern having microstratigraphic significance may be observed. Judging from previous trials, an exposure period of several months will be required for sufficient track density to accumulate so that it can be recorded on the film. The specimens are now being maintained under refrigeration to minimize background fogging.

Other recent results of this investigation may be summarized as follows:

Identifiable plant materials, from which derivation of the degraded organic matter in the shale must be inferred, include Foerstia, a group of planktonic marine algae that may be distantly related to modern Phaeophyceae. Abundant material has been prepared for paleontologic purposes to illustrate features of species of Foerstia which are widely dispersed in the lower parts of the Ohio and Chattanooga shale in Tennessee, Kentucky and

Ohio. Although individuals of Foerstia are small they occur in such numbers that they are next to "spores" in contributing identifiable plant remains.

Some of the first material abundantly available was obtained at Flint Park, a few miles north of Columbus, Ohio, in the lower portion of the Huron, or Ohio, shale. The laminated black shale here is not known to be highly radioactive but it seemed advisable to prepare as pure a sample of Foerstia as possible for chemical determinations, in view of the lack of any comparable data.

The shale was dried and crushed. A rough separation of Foerstia thalli was made by floating them on CCl_4 at specific gravity of 1.59. Individual thalli were subsequently picked from the "Foerstia concentrate" until about three grams were accumulated. The flakes of coaly algal tissue, showing very little evident mineral matter, were crushed in a mortar until reduced to pass a 65 mesh screen. This sample was divided into two and bottled on the assumption that both samples were equivalent.

One of these bottled samples was again subdivided and half of it treated with cold analytical grade hydrofluoric acid in a wax vessel for approximately three days in an effort to further remove any mineral matter present. To complete the suite of samples a portion of the original organic shale matrix, still containing some fragments of Foerstia, was also crushed to -65 mesh to provide contrasting data.

The shale matrix sample and about $1\frac{1}{2}$ grams of the hand picked Foerstia were sent to the Washington Trace Elements Laboratory for ash, colorimetric oil assay, uranium and semi-quantitative spectrographic determinations.

A portion of somewhat less than a gram of the "natural" hand-picked Foerstia, and the portion that had been treated with hydrofluoric acid,

were sent as samples 3 and 4 to the Clark Microanalytical Laboratory in Urbana Illinois, for determination of organic elements approximating those included in the "ultimate" type of coal analysis.

The results of these four sample determinations are given below in tables 2 and 3.

Data from the two sets of determinations are less in agreement on ash content than was anticipated, the "Hand Picked Foerstia" and "Natural Foerstia" of the two tables presumably representing duplicates of the same material. Difficulties are multiplied in attempting analyses of such small samples and one probably should not expect closely compatible results in an initial effort of this type. Evidently it is much more difficult to reduce the mineral matter to relatively low levels than was first anticipated, even with hydrofluoric treatment.

These data are presented now because they apparently are unique. Similar suites of determinations from material obtained at a few other localities would aid in showing whether any of the trends of variation between the organic concentrate and matrix are consistent and whether any systematic variation occurs in the organic elements as it does in coal formed from land plants in a different depositional environment.

Other identifiable remains of plants in the Chattanooga shale include drift wood of Callixylon, both silicified and as bituminous coaly streaks. One large algaoid plant, Prototaxites, has been more rarely identified. Materials of both types have been obtained for study and illustration. In a few instances chemical determinations will be obtained on the nearly pure coaly mineral-free streaks that probably represent the bituminous remains of Callixylon. Some of these have proved unusually radioactive.

Table 2.--Results of ash, oil assay, uranium and spectrographic determinations of matrix and hand picked organic matter (Foerstia)

	SHALE MATRIX	HAND PICKED FOERSTIA
(1) ASH (air dry basis)	-- 81.5%	----- 55.8%
(2) OIL ASSAY (air dry)	-- 1.6%	----- 10.0%
(3) URANIUM (air dry)	---- 12 ppm (0.0012%)	-----16 ppm (0.0016%)
URANIUM (in ash)	---- 15 ppm (0.0015%)	-----28 ppm (0.0028%)

Semi-quantitative spectrographic determinations of ash or incinerated samples

(4) COPPER (Cu) concentrated about ten times in ash of picked Foerstia
Matrix = .01 - .001% Foerstia = .1 - .01%

(5) Other elements that may be slightly concentrated in ash of Foerstia

Molybdenum (Mo)	.1	- .01%	magnitude of occurrence
Manganese (Mn)	.1	- .01%	" "
Vanadium (V)	.01	- .001%	" "
Yttrium (Y)	.01	- .001%	" "
Uranium (U)	.0015%	(matrix) - .0028%	(<u>Foerstia</u>)

(Uranium determinations not spectrographic)

(6) Elements that may be to some extent deficient in ash of picked Foerstia

Strontium (Sr)	.1	- .01%	magnitude of occurrence
Chromium (Cr)	.1	- .01%	" "

(7) Elements present in about the same apparent concentration in both samples

Si, Al	----more than 10%	-----magnitude of occurrence
Fe, K, Mg	----- 10. to 1.0%	" "
Ti, Ca, Na, Ba	---- 1.0 to 0.1%	" "
B, Pb, Ni, Co, Zr	0.1 to .01%	" "
Ga, Sn, Sc	----- .01 to .001%	" "
Yb, Be	----- .001 to .0001%	" "

(8) Elements in lower than threshold quantities in both samples

Analytic Thresholds

Ag	-----	less than .0001%
Bi, Ge, In	-----	less than .001%
Au, Cd, Dy, Eu, Er, Gd, Ho, La, Lu, Nb)	-----	less than .10%
Nd, Pd, Pr, Pt, Rh, Ru, Sb, Tb, Tm, Zn)	-----	less than .1%
As, Ce, Hf, Hg, Ir, Li*, Os)	-----	less than .1%
P, Re, Sm, Ta, Te, Th, Tl, W)	-----	

* No special methods were used to determine Li, Cs, Rb, or F.

(9) About twenty-three elements are unstable or otherwise unsuited to spectrographic determination.

Analytic determinations by Washington Trace Elements Laboratory, USGS, under direction of John C. Rabbitt; Chemistry by Maryse Delevaux; Spectrography by Charles Annell.

Table 3.--Results of organic element microanalysis of Foerstia

Constituent	"NATURAL" Foerstia		Foerstia, HF Treated	
	Vacuum Dried 56° C Wt. Loss 1.71	Calc. Ash Free	Vacuum Dried 56° C Wt. Loss 1.71	Calc. Ash Free
Ash	80.75		41.53	
Carbon	11.19	58.13	36.88	63.07
Hydrogen	1.80	9.35	3.81	6.52
	Wt. Loss .140		Wt. Loss .122	
Nitrogen	1.15	5.97	1.03	1.76
	Wt. Loss .71		Wt. Loss 1.62	
Sulfur	3.42	17.77	8.89	15.18
Oxygen, + determinative errors		8.78		13.47
Total	-----	100.00	-----	100.00

Analytic determinations by Clark Microanalytical Laboratory, Urbana, Illinois: D. Dickenson, Chief Chemist.

Seven varieties of anomalous spore-like bodies are distinguished among organic constituents of the Devonian black shale; in addition spores of undoubted land plants have been found in some abundance in beds of Chagrin age in Ohio. These contrast strongly with the spore-like microfossils whose affinity is uncertain and which are best referred to the form genus Tasmanites. Usually the latter types are dominant and land plant spores are rarely seen. New material from core sectors recently supplied from drilling in Tennessee should assist in making a more systematic survey than has heretofore been possible.

Uranium in asphaltites

Reconnaissance for uranium-bearing asphaltites
by W. J. Hail

The reconnaissance investigation for uranium-bearing asphaltites will consist of: systematic sampling of known asphaltite deposits; a study of the basic geology of these deposits; and a regional reconnaissance to discover new deposits.

It is planned first to visit areas known to contain large deposits of asphaltites similar to those near Vernal, Utah, and to sample these deposits systematically for their uranium and other trace element content. Smaller deposits known to be uranium-bearing will also be sampled systematically. The basic geology of those areas found to contain uranium-bearing asphaltites will be studied with a view to determining the geologic structure or setting which appears favorable for the concentration of the uranium and other trace elements. This knowledge will then be applied when other areas are prospected. The field reconnaissance will also be extended to other areas

in which asphaltites have been reported, in order to determine the extent of such rocks, and whether or not they contain uranium.

If the reconnaissance field investigation discovers areas containing deposits of uranium-bearing asphaltites which are of economic interest, these areas will be outlined for more intensive and detailed work.

Core processing
by J. M. Schopf

Cores of Dakota lignite

Since January 1, 1953, eighty-five and one-half linear feet of core from Holes SD-10 and SD-19 in the Slim Buttes area of South Dakota have been described and sampled in detail for radiometric determinations. Seven bed samples have been prepared for standard coal analyses including real specific gravity, proximate, ultimate, Btu, forms of sulfur and ash fusibility determinations. About 250 samples, representing two to six inches of core thickness, were studied as a basis for establishing a radioactivity profile of both the coal and non-coaly cores that were shipped to the Coal Geology Laboratory from the drill site. The detailed radioactivity profiles also were used as a basis for determining how the small samples should be combined for sake of efficiency in analysis, in submitting samples for accurate determinations of uranium at the Washington Trace Elements Laboratory.

One hundred thirteen samples of coaly and non-coaly rock were submitted for this purpose. Coaly samples, owing to the notable initial concentration of mineral elements in their ash, appear to represent a simpler problem for analysis with precision (with reference to the raw coal) than samples composed dominantly of mineral matter. The samples were divided into these two classes; coaly samples may be analyzed with good accuracy by

routine procedures and results obtained sooner. Non-coaly samples will require a longer period for analyses of equivalent precision. It is not expected that results of immediate economic value will be obtained in analysis of the non-coaly rocks in this region but it is highly desirable that this data be obtained from these two drill holes, which have afforded better than usual material, as a matter of basic geologic information.

Six laboratory reports have been issued in description of the lithologic features of these cores and as a record of detailed sampling and radiometric determinations. Copies of descriptive reports have been provided to those immediately concerned with the field project. Charts illustrating radiometric profiles from these drill holes are included in this report as figures 15, 16 and 17.

Results are plotted on these three charts in units of pulses per minute per gram (P/M/G). Calibration in terms of equivalent uranium is difficult owing to diversity of samples studied but most recent analytic results on comparable materials usually have shown 15 to 20 parts per million uranium for each P/M/G. Of greater geologic significance is the generally good relative accuracy of the P/M/G results.

Cores of Chattanooga shale from the
Youngs Bend area in central Tennessee

One hundred and eighty feet of black shale core from six Youngs Bend holes has been sliced and accurately sampled at the Coal Geology Laboratory for chemical determinations and to provide correlative materials for research by different investigators and for a Bureau of Mines core-library reserve. One hundred forty-four samples have been shipped to the Trace Elements Laboratory as a result of this work.

SUMMARY P/M/G RESULTS, HOLE SD-10
SLIM BUTTES AREA, HARDING CO., SOUTH DAKOTA

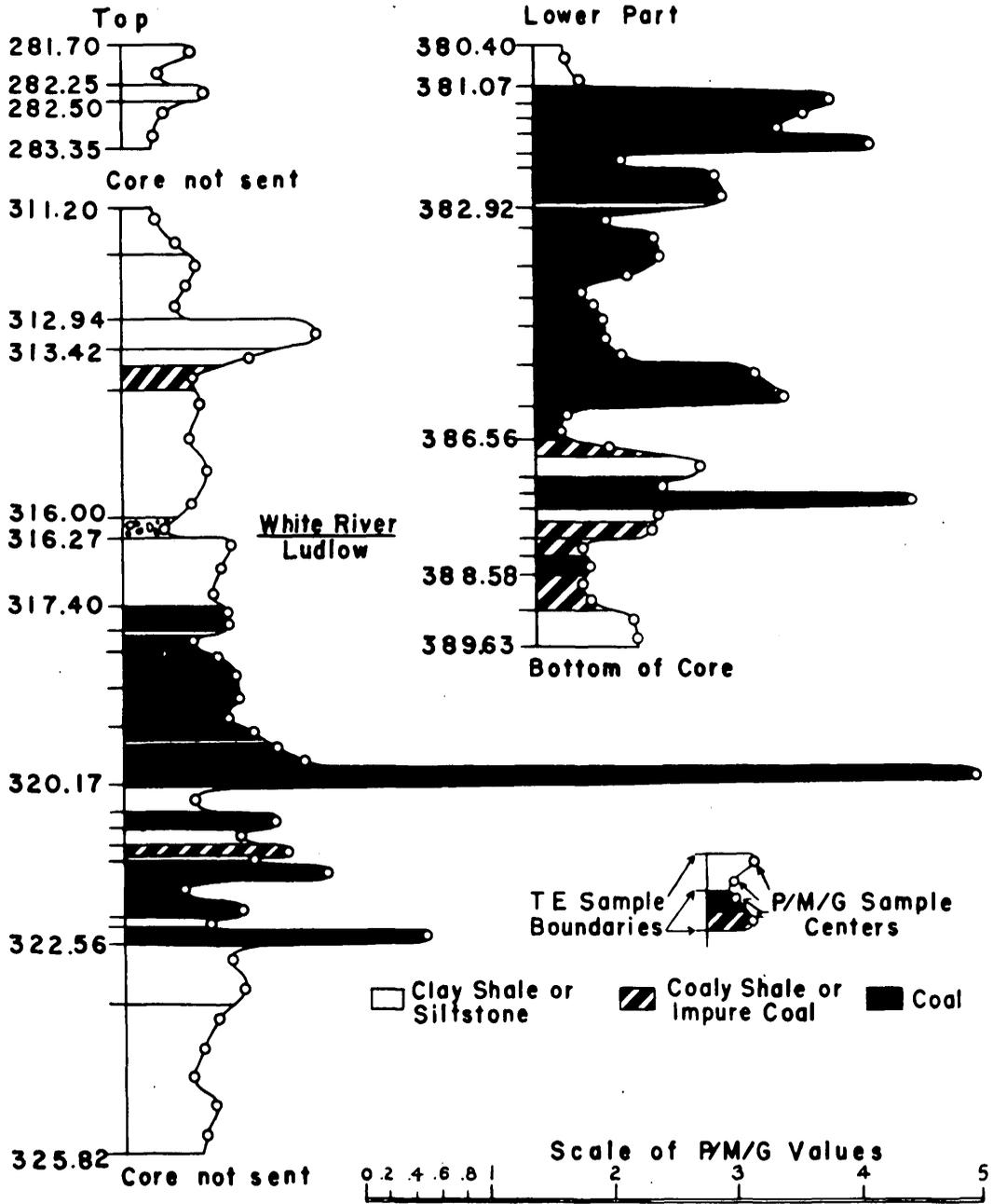


Fig. 15

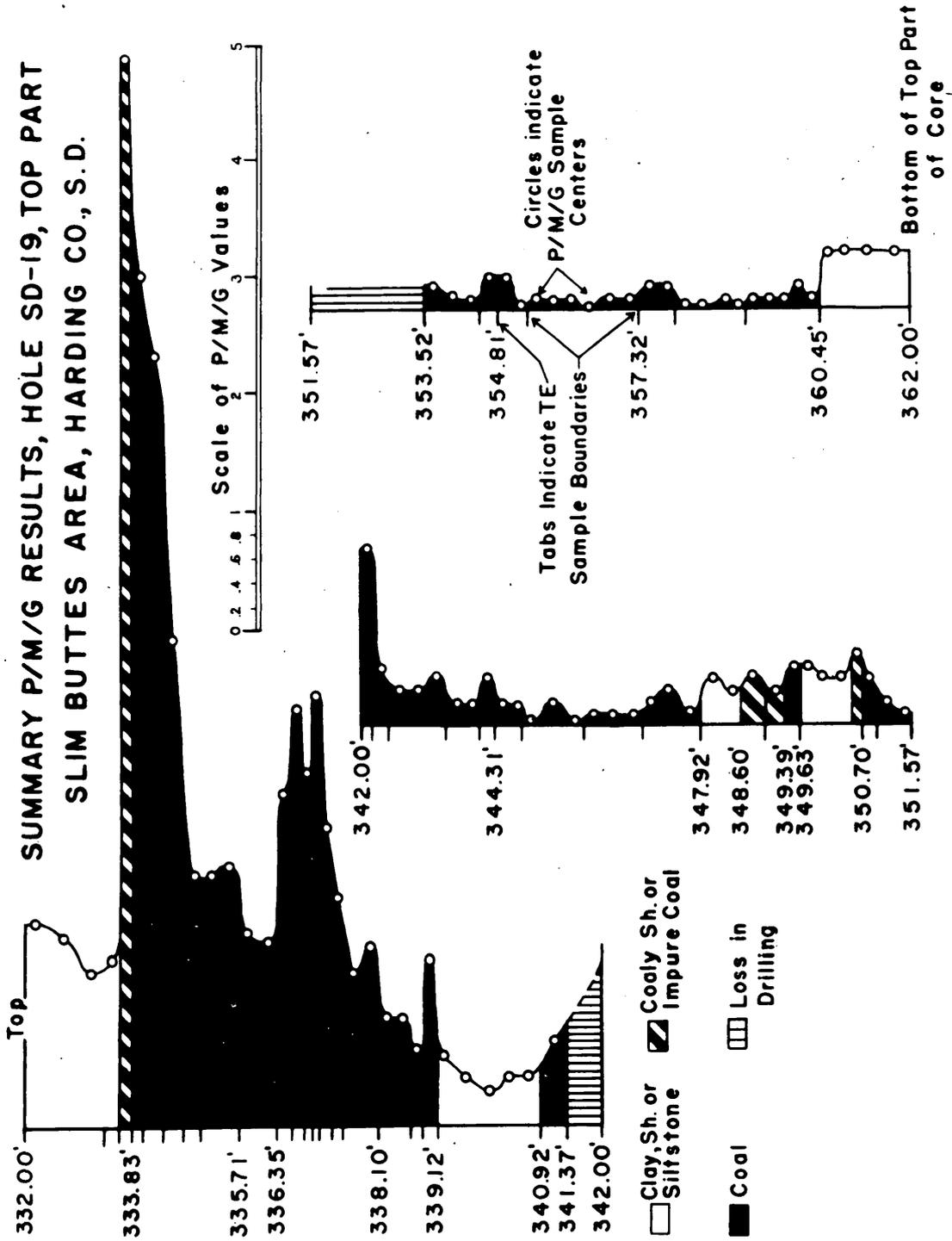


Fig. 16

SUMMARY P/M/G RESULTS, HOLE SD-19, LOWER PART
SLIM BUTTES AREA, HARDING CO., S. D.

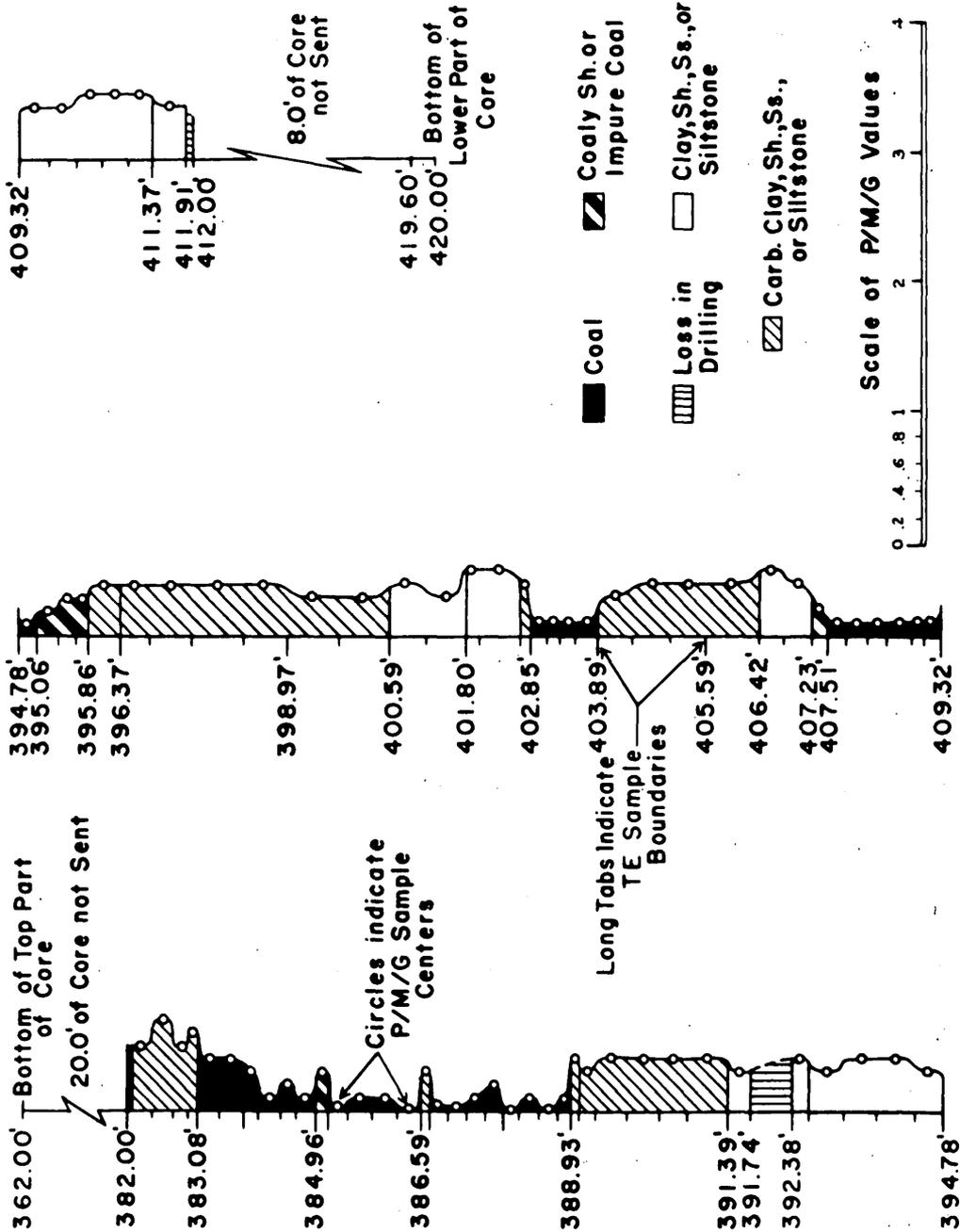


Fig. 17

Samples from other sources

A series of thirty core chip samples, representing a thickness of 106 feet of Mississippian age black shale from an oil test well in Alabama, were submitted by Wilbert C. Hass for radiometric survey. None of the samples were sufficiently radioactive to suggest higher concentrations of uranium than about ten parts per million, and for this reason no further analyses were requested.

Core from Hole SD-10 was recovered traversing the unconformity between White River beds (above) and the coal-bearing Ludlow formation (fig. 15). The characteristics of these non-coaly beds are of interest in view of evidence which suggests concentration of uranium in coal by downward percolating ground waters.

Distribution of radioactivity in the topmost coal bed below this unconformity is of considerable interest also, since it differs from the typical distribution of uranium in the Dakota uraniumiferous lignite beds previously examined. It compares much more favorably with the distribution previously noted for sub-bituminous coal beds of the Red Desert region in south central Wyoming. According to J. R. Gill, geologist in charge of the Dakota project, this is not the Mendenhall coal bed that contains the chief resources of uranium in the Slim Buttes area.

The radiometric profile established for Hole SD-19 is relatively typical of the top-preferential pattern of radioactivity that has been established in other drill holes and from weathered outcrop samples of the Mendenhall coal bed. This comparison holds even for the high radioactive values found in the impure top layer of the bed. Some secondary peaks of radioactivity also are observed in the coal at depths of about 336 feet and at 342 feet.

Owing to about 7 inches core loss above 342 feet it is difficult to know whether a top-preferential or a centrally placed anomaly is indicated by the moderate radioactivity in the sample just below this depth.

All the purer coal samples below 343 feet depth in Hole SD-19 show levels of radioactivity less than half that of the associated clay shale, siltstone and sandy beds. In this respect these coals are typical of coal in general which is known to be characteristically deficient in radioactivity. This also serves to further emphasize the exceptional nature of certain western coals that do show significant concentrations of uranium.

Research investigations on the petrographic composition of reserve portions of these two coal cores are now in progress and will be reported subsequently in another connection.

SEARCH FOR AND GEOLOGY OF URANIUM IN PHOSPHATE

Northwest phosphate
by R. W. Swanson

During the last six months principal project efforts were devoted to compilation of stratigraphic and analytical data. The format for compilation of stratigraphic data for columnar sections was revised and to date nearly 70 sections have been prepared. Other efforts during this period have been devoted chiefly to report preparation.

Progress toward release of data in the last six months is as follows: Circulars 208, 209, 210, 211, presenting analytical data on measured sections of the Phosphoria formation, were published and the companion TEI reports 183, 184, 185, and 186, containing data on the uranium content of these sections, were transmitted to AEC. Three similar pairs of reports have been submitted for publication, and six other pairs are prepared and will be submitted for processing soon. A report summarizing data on samples collected in 1952 will be placed on open file shortly. The geologic map and structure sections of the southwest quarter Willis quadrangle, Beaverhead County, Montana has been placed on open file and will be transmitted as a TEI, and the geologic map and text of the Centennial Range, Montana-Idaho has been transmitted as TEI-323 and placed on open file. Geologic maps and reports of the Johnson Creek and Dry Valley, Idaho, quadrangles have been completed and are being reviewed prior to transmittal for publication. A progress report, summarizing work accomplished over the whole field thus far, was transmitted to the AEC as TEI-246, will be placed on open file in June, and then published as a circular. A chart showing the stratigraphic section in the Soda Springs quadrangle, Idaho, and a paper on the Phosphoria formation

in southeastern Idaho and western Wyoming were prepared and transmitted to the Intermountain Association of Petroleum Geologists for publication in its guidebook in June. Because of the availability of these reports, now or in the near future, as well as their volume, it is not desirable to summarize all of them here, but summaries of those reports of most significance and interest as well as summaries of other investigations that have not reached publication stage are presented below.

Plans for the summer field season include: (1) stratigraphic correlation studies of Phosphoria formation strata throughout the field; (2) limited sampling and description of stratigraphy at critical spots such as the type locality of the Park City formation near Cottonwood Canyon, Utah, near Blackfoot Reservoir, Idaho, and in the northern part of the field in Montana near Philipsburg, Maxville, and Elliston where our data are sparse but valuable phosphate deposits are known to occur; (3) limited reconnaissance in unexplored parts of the field such as northeastern Nevada and north-central Wyoming; (4) continuation of geologic mapping in the Aspen Range-Dry Ridge area of Idaho; (5) mine mapping, section measuring, and field checking in the NW $\frac{1}{4}$ Willis quadrangle, Montana; (6) completion of mapping and field checking in the Virginia City and Eldridge quadrangles, Montana; and continuation of petrologic, geochemical, and paleontologic studies.

Phosphoria formation in southeastern Idaho
and western Wyoming

by V. E. McKelvey, R. W. Swanson and R. P. Sheldon
(partial abstract of paper to be published in the 1953 I.A.P.G. Guidebook)

The sections of the Phosphoria formation described from southeastern Idaho and western Wyoming illustrate the transition from geosynclinal to platform facies. This transition between the two facies took place along a

northward-trending zone that fluctuated from west to east in the vicinity of the Idaho-Wyoming boundary. The rocks deposited in this area are consequently of diverse lithologic types but they display an eastward decrease in total thickness of the Phosphoria; eastward overlap and wedgeouts; and facies changes that result in an eastward decrease of phosphate rock, carbonaceous matter, and bedded chert and in an increase of carbonate rock, nodular chert, and sandstone.

Progress report on investigations of western phosphate deposits
by R. W. Swanson, V. E. McKelvey and R. P. Sheldon
(partial abstract of TEI-246)

The Bear River region of southeastern Idaho and adjacent parts of Wyoming and Utah contains the greatest total amount of phosphate as well as the thickest beds of high-grade phosphate, though some high-grade beds of minable thickness occur in other parts of the field, particularly western Montana. Several valuable deposits have been discovered during this investigation, most noteworthy of which are a 6-foot bed of acid-grade rock in the Centennial Range at the Montana-Idaho state line; a 12-foot bed of 33 percent P_2O_5 rock in the Caribou Range, Idaho; several strippable deposits of furnace-grade rock in southeastern Idaho; and a 12-foot bed of 20 percent P_2O_5 rock at the top of the formation north of Cokeville, Wyo.

Stratigraphy of the Phosphoria formation
in northwestern Wyoming
by R. P. Sheldon
(partial abstract of paper in preparation)

The Phosphoria formation consists of three major lithologic facies; a bedded chert, dark pelletal phosphorite, and dark phosphatic mudstone facies; a cherty limestone, sandstone, and sandy phosphorite facies; and a red bed,

carbonate, rock evaporite facies. The general distribution of these facies was controlled by depth of water and configuration of the Phosphoria Sea which was in turn controlled by the major structural units of the area, which were: a miogeosyncline in southeastern Idaho, a platform area in western Wyoming and a land area in central Montana. Thus the chert-phosphorite-mudstone facies is found in the miogeosynclinal area and the limestone and sandstone facies is found on the platform area. The gradation zone between these two structural units shows a complex interfingering of the two facies types which was determined by oscillating structural movements.

Stratigraphy of the Phosphoria formation
in part of southwestern Montana

by E. R. Cressman

(abstract of paper read before GSA at Butte, Montana, May 8)

In much of southwestern Montana the Phosphoria formation of Permian age is divided into five members. These are, in ascending order, a quartz sandstone-dolomite member (not discussed), a thin lower phosphatic shale member, a dolomite-chert member, an upper phosphatic shale member, and a chert-quartz sandstone member.

The lower phosphatic shale is 30 feet thick immediately west of Lima, but it thins to a feather edge 60 miles to the north and east. A thin basal phosphate bed is continuous over most of the region.

The dolomite-chert member is 290 feet thick immediately east of Lima, bedded chert comprising the lower 110 feet. The dolomite grades westward into dolomitic sandstone, and both chert and dolomite thin north and east, sandstone beds becoming more prominent.

The upper phosphatic shale member is generally 60-80 feet thick, but it ranges from possibly as much as 150 feet west of Lima to five feet in the

east. The thickness of the member is governed largely by the amount of fine-grained detritals. The phosphate content is independent of the abundance of fine-grained detritals.

The chert-quartz sandstone member is slightly more than 100 feet thick. Facies changes between chert and sandstone are common and abrupt. Chert may intertongue with or grade into mudstone both on the extreme east and west.

Members behave as units, facies changes occurring largely within rather than between members. The source of fine-grained detritus is not known, but quartz sand was apparently derived from the east, northeast, and west.

Permian phosphate deposits of Montana
by R. W. Swanson
(abstract of paper read before GSA at Butte, Montana, May 8)

In Montana two of the five members of the Phosphoria formation are phosphate shales; both shale members contain most total phosphate in the southern part of the region. Acid-grade rock of the lower shale is restricted to the Centennial Range. Attractive upper shale phosphate occurs only north of Dillon. Phosphate occurs as brownish-black oolitic carbonate fluor-apatite interbedded with dark mudstones, locally oil-rich, whose thickness and spacing control the grade of minable units. Sandstone interbeds are important in the Centennial Range. Besides the active Garrison and Melrose fields, attractive areas for mining include the Centennial Range, the Elliston area, and the area between Anaconda to Maxville.

Preliminary report on geology of Centennial Range,
Montana-Idaho, phosphate deposits
by F. S. Honkala
(partial abstract of report to be placed on open file in June)

In the Centennial Range the Phosphoria formation is divisible into five members, designated A to E, from the bottom to the top of the formation. The

B and D members contain phosphate rock. The B member contains six feet or more of high-grade phosphate rock, mostly in one layer, and is the chief potential minable bed. The formation dips gently southward and is overlain by varying amounts of overburden. Underground mining would seem to be the best method of potential exploitation of the deposit, but core drilling and further trenching are needed. High-grade phosphate rock reserves in the Centennial Range may total scores of millions of tons.

Control of rare element concentrations in sea water
by K. B. Krauskopf
(abstract of report in preparation)

The ions of thirteen metals, Cu, Zn, Cd, Hg, Ag, Pb, Bi, Mo, W, V, Co, Ni, and Cr, were studied from the standpoint of their precipitation by normal ions of sea water, precipitation as sulfide, and adsorption by inorganic and organic materials.

Preliminary conclusions indicate that equilibrium with the normal ions of aerated sea water in the ranges of temperature and pH recorded for the oceans cannot be responsible for the observed rare metal concentrations. Sulfide ion is a possible control for the concentrations of Cu, Zn, Pb, Ag, Hg, Cd, Bi, and Cr; though Cu, Zn, Pb, Cd, and Bi are also quite effectively removed by various adsorbents. Co and Ni will probably be adsorbed on many things. Ag and Hg are very effectively adsorbed by dead plankton. W is very strongly adsorbed by MnO_2 , and V by Fe_2O_3 . No very effective mechanism for removing Mo is obvious from the experiments. Cr is precipitated in the presence of H_2S as a hydroxide, so the control here is not a sulfide formation but reduction of chromate to the trivalent form. An especially effective adsorbent of Pb is freshly precipitated calcium phosphate.

15

Averages of spectrographic analyses of samples of the Phosphoria formation show a clear enrichment, by a factor of at least 2 over both the crust and average shale, of Ag, V, Pb, Cr, Ni, and Mo. All of the elements show maximum enrichment in certain horizons far greater than their average enrichments. Any element is seldom enriched above average by itself. The most frequently occurring pair is V and Mo, the most frequent triplet is V, Mo and Cr, the most frequent quadruplet is V, Mo, Cr, and Ni. Silver in many samples shows special enrichment with one or more of this group; Cu and Zn are also common associates. Lead shows the least relationship of its zones of special concentration with those of other elements.

Uranium has not yet been studied because most of the work to date was done in Oslo, Norway, where the apparatus necessary for uranium analyses was not available.

Southeast phosphate

Geologic studies
by C. B. Hunt and J. B. Cathcart

It is planned to provide the AEC during the next 15 months a series of reports that will assemble rather fully, synthesize, and evaluate the data that have been gathered by the Geological Survey's projects in the land-pebble district of Florida. These data when assembled in accessible form should provide a basis for: (1) the AEC to plan further operations in the district, and (2) determining what gaps there are in the information in order to judge the degree to which the Survey has completed its mission for the AEC in the district. With these objectives in mind the Survey's projects in the district are being reoriented.

There will be a comprehensive summary report by Cathcart and others on "The economic geology of the land-pebble phosphate district, Florida". The first draft of the part of this report on the aluminum phosphate zone, including recommendations for prospecting, will be ready on or before June 1954. Data from mine face samples and prospecting is being assembled and the first results from the Pauway Mine indicated that high-grade leached zone material might be found to the south and east, down slope. Two drill holes were, therefore, put down in sec. 13, T. 29 S., R. 24 E., to explore this possible trend. Both holes had high peaks 2 to 4 feet thick of over 4000 counts per minute (4000 counts is equal to 0.025 % eU). Further trends may be picked up that will be incorporated in this first report.

The general scope of the comprehensive report, to be transmitted some-time later will be as follows:

Introduction: location, physical and human geography, previous work, history of this project, annotated bibliography.

Stratigraphy:

Pre-Miocene deposits: brief resume only.

Miocene deposits: Tampa, Hawthorn, Duplin, Buckingham, and Tamiami. For each: distribution, lithology, thickness, paleontology, age, correlation, representative sections in and around the land-pebble district.

Pliocene deposits: Bone Valley, Alachua, Citronelle, Caloosahatchee. General descriptions as for Miocene formations but stressing relationship to and bearing on the Bone Valley formation and its resources.

Pleistocene and Recent deposits: marine terrace deposits, fluvial terrace deposits, soils, weathering profiles and the weathering processes that have been operative.

Structure: folds: Ocala uplift and minor folds; faults related to the folds; faults and joints related to sinkhole collapse.

Economic geology:

General discussion of phosphate deposits in the southeastern states: river pebble, land-pebble, hardrock and softrock deposits in Florida; deposits in Georgia and South Carolina.

Deposits in the land-pebble district: general description of the deposits.

Deposits in the Miocene formations.

Deposits in the Bone Valley formation.

Deposits in other Pliocene and in Pleistocene deposits.

Relation of the deposits to the structural features.

Relation of deposits to weathering profiles.

Mineralogy and chemistry of the deposits: Content of F_2O_5 , U, and other; distribution of these in the deposits; nodular, platy, and colloidal apatite; aluminum phosphate; clay minerals; carbonate minerals, heavy minerals.

Mining and production: index of mines: mine methods, early hydraulic mining, modern dragline mining; history of mining, exploration, and production; types of ore; mine costs.

Origin of the deposits: review of various theories, residual, depositional, other; evaluation of the geologic relations and preferred theory of origin.

Reserves.

It is expected that this report will be accompanied by maps of the mines; maps showing areas mined, drilled, or otherwise explored; and maps showing variations in thickness and grade of the deposits in the district. The report will include the results of drilling, sampling, and gamma-ray logging to date and the results of the several hundred exploration holes that will be drilled.

In addition to this general comprehensive report it is planned to prepare a series of more detailed reports on specific geologic problems.

A study by Z. S. Altschuler, assisted by J. P. Owens, R. Berman, and E. Young will be directed towards the petrology and stratigraphy of the ore deposits in the Bone Valley formation. (See following section.) This study aims at understanding the origin and occurrence of the phosphate and uranium deposits in the different facies of the Bone Valley formation, the redistribution of uranium by weathering, and the relation of this weathering to post-depositional basement collapse and to the weathering history of possibly related coastal plain sediments that are under investigation in other projects. To achieve this will require stratigraphic separation of deposits represented by residual weathering of the Miocene limestones, Pliocene fluvial and/or marine deposits, and Pleistocene fluvial and/or marine deposits. The descriptive petrography involved in this project, including optical, X-ray, and chemical studies, is already well under way. The stratigraphic studies will involve additional mapping during the coming year. A report on this study will be completed about June 1954 and a final report in form suitable for publication as a bulletin or professional paper would be ready about June 1955.

Four other studies are intended to determine the limits of the Bone Valley formation, which is the one containing the principal resources, and to determine its stratigraphic relationship to deposits in adjoining areas that have been correlated with the Bone Valley. The northern limits of the Bone Valley formation and its relationship to the Alachua formation will be studied and reported upon by Ketner. The eastern limits of the Bone Valley formation and its relationship to the deposits that have been mapped as Citronelle formation will be studied and reported upon by McGreevy. The western limits of the Bone Valley formation, its relationship to the Pleistocene marine terraces and deposits, and the relationship of the weathering

profiles to these will be studied and reported upon by Petersen. The southern limits of the Bone Valley formation and its relationship to the Callosahatchee and Tamiami formations will be studied and reported upon by Bergendahl. These studies, like that of the Bone Valley formation, will involve considerable attention to mineralogy, geochemistry and sedimentary petrology. It is expected to drill, log, and, as necessary, sample a few hundred test holes, using the mobile drills. The bedrock types will be correlated with the types of surficial sediments to determine the degree to which the mineral bearing deposits are the product of transportation and deposition and the degree to which they are the product of residual weathering of older rocks. Each of these studies will be the subject of a report that is to be completed about June 1954 and thereafter be used as basis for a manuscript to be published as a U.S.G.S. bulletin.

Still another study, by Carr and Alverson, will concentrate on the stratigraphy and potential resources in the Miocene and other pre-Bone Valley formations on the southwest flank of the Ocala uplift, mostly along the west edge of the land-pebble phosphate district. This report also is to be completed about June 1954 and thereafter be used as basis for a manuscript to be published as a U.S.G.S. bulletin.

All these studies will involve some additional field work but to a considerable degree they will be based upon field work already completed. Additional information, for example, can be expected from the 120 holes that will be drilled radially across the edges of the district. This drilling started on May 26, about one mile north of Plant City, Hillsborough County, Florida, and the radial lines will be drilled in a counter-clock wise direction around the district. The holes will be logged and sampled as a part of the

geologic studies of the edge of the Bone Valley formation. Gamma-ray logs will be obtained of these holes.

A brief survey to test the possible use of geobotanical prospecting in the Florida land-pebble deposits was made during this period but the assays have not yet been received. (See section on sandstone-type deposits, Geobotanical research, by H. L. Cannon.)

A contract for drilling areas to be mined prior to 1965 have been let by the AEC to Swift and Company, and about 10 holes have been drilled and logged. In the next few months similar contracts will be arranged with Coronet, American Agricultural Chemical Company, and American Cyanamid Company.

Southeast phosphate mineralogic and petrologic studies
by Z. S. Altschuler

This report summarizes studies on southeast phosphates for a period of approximately 10 months from August 1952 until May 15, 1953. Work during the first eight months of this period was concerned mainly with problems of variation in the mineralogy of the leached zone and the work done between April 1 and May 15 was devoted to field geologic studies of the Bone Valley formation.

Alteration studies

Petrologic studies of seven sections in a mineface at Homeland are being made by comparing the mineralogy and chemistry of stratigraphically equivalent samples. It had been found (TEM-237) that the aluminum phosphate zone (leached zone), transgressed the original stratigraphy in this mine thus making possible a comparison of the same rock in various stages of alteration. Certain

mineralogic associations and successions were observed to prevail in all seven sections. At the base of each section, in apparently unaltered material, montmorillonite and apatite occurred. Going up, in each section, with the onset of vesicularity and secondary white discoloration, both pseudowavellite and kaolinite occur together with apatite and montmorillonite. Closer to surface, as the alteration becomes more intense, pseudowavellite and kaolinite are the main components. Millisite may occur in the zone characterized by pseudowavellite. At the top of the column wavellite appears as a major phase in the more altered sections but is present also in the less altered ones. In addition quartz which is a major constituent of all the samples increases regularly upward in each section, as expected. The succession described above can be found also in some single beds or units traced laterally from less through more leached sections.

The uranium contents of these sections show an enrichment occurring approximately at that part of the section where pseudowavellite first appears and apatite is still present. This corresponds to secondary downward enrichment in uranium and has been also demonstrated in other studies (TEI-102). The mechanism suggested for this downward enrichment is the filtering of uranium carried in solution by apatite in the earliest stages of alteration. Thus the first appearance of pseudowavellite is an index to that stage in the alteration in which the apatite nodules, only very slightly replaced, are nevertheless softened and highly porous and act, in effect, like sponges upon the uraniferous solutions.

Mechanical analyses and heavy-mineral studies were made on samples straddling the boundary between the pure quartz surface sands and the immediately underlying clayey quartz sands in the several mines of the land-pebble district. This work bears directly on two major problems of the land-pebble

field, the origin of the surface sands, and source of the uranium in the aluminum phosphate zone (leached zone). Field evidence that part of the loose surface sands may derive residually from material such as underlies it, exists in the form of irregular and gradational contacts. On the other hand, it is possible that an erosional contact was once present which was later irregularly altered and obliterated. In either case, the uranium now present in the aluminum phosphate zone could be the concentrated product of an originally thicker section of slightly phosphatic, clayey, quartz sand. Mechanical analyses were therefore made of the lowermost loose quartz sand and the uppermost phosphatic quartz sand in each of the seven Homeland sections described above (the Homeland analyses were made in 1951), of a similar pair of samples in the Varn mine and a group of samples through several feet each of loose quartz sands and phosphatic and clayey quartz sands in a single section of the Jaynee Jay mine.

In the section in the Jaynee Jay mine a ground-water podzol occurs in the loose surface sands and the underlying clayey sands contain a hardpan and several color zones. The section thus appears to have several distinct breaks particularly as weathering has etched out these zonal differences. Samples were taken in all of the apparent units.

In the Homeland samples the cumulative curves of the grain size distribution for all of the samples were virtually identical, as were the individual size parameters such as the median and quartile values. The Jaynee Jay samples showed the same striking uniformity in size characteristics.

Heavy-mineral studies of the 250 and 325 mesh fractions of the Jaynee Jay samples showed the same uniformity. In the results shown in the table below samples 5 through 7 represent approximately the top foot of clayey and phosphatic quartz sand and 8 through 12 represent the entire loose quartz sand, here 4 feet thick.

Table 4.--Heavy-mineral contents of overburden sands and aluminum phosphate zone in the Jaynee Jay mine, Florida.

Sample No. and description	Minerals: Relative weight percents							
	ilmeneite	tourmaline	zircon	rutile	staurolite	sillimanite	kyanite	biotite
FP-12, Quartz sand, dk. gray, surface root zone	77	3	2	3	7	5	3	0
FP-11, quartz sand, white "leached" horizon	54	4	20	8	4	6	4	0
FP-10, quartz sand, dk. brown organic-rich base of podzol	47	7	20	8	0	13	5	0
FP-9, quartz sand, tan	58	3	22	4	2	5	6	0
FP-8, quartz sand, light tan	50	7	20	8	3	8	4	trace
FP-7, phosphatic quartz sand, compact	54	4	20	6	4	11	1	0
FP-6, phosphatic quartz sand, loose, mottled	46	6	19	10	2	13	4	0
FP-5, phosphatic quartz hardpan	60	1	10	18	6	11	4	0

The two samples studied at Varn represent the case of an apparently regular contact between the loose quartz sands and the underlying clayey sands. It is interesting to note therefore that the size analyses reveal a displacement towards the finer size in the loose surface sands, the median grain size shifting from 0.3 mm. in the clayey sands to 0.2 mm. When compared with the identity that prevails at Homeland and other mines this slight change seems significant. It indicates, at least, that both residual and depositional relations may obtain between the upper loose quartz sands and the underlying clayey sands over the field and that many more such analyses must be made before the prevailing relations can be established.

Field work

With the expansion of the aims of the laboratory group to include study of the stratigraphy and field relations of the Bone Valley formation, field work during the period April 1 to May 15 was devoted mainly to stratigraphic mapping and section description. Due to a slowdown in the mining at the Sydney mine it was possible to study in detail the relations among the Hawthorn formation. Of greatest interest was the fact that different types and degrees of bedding and bedding extent could be seen in the Hawthorn and Bone Valley formations. In addition, at that position at which the change occurred, both crossbedding and extensive units of uniform lithology occurred and extensive and lithologically uniform deposition characterized most of the superincumbent deposit. Below this change in the section, the Hawthorn formation consisted of irregularly altered dolomite and clay with discontinuous bands or beds and containing poorly sorted and irregularly dispersed sand and pebbles. Discordant patches and seams of pebbles of clay are common

and individual original beds or weathering zones are unconformably over-
ridden by the more extrusive and uniform deposit above.

Work during the next 6 months will be done on stratigraphic correla-
tion and the construction of cross sectional maps.

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

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

Field studies, which were completed in February 1953, have provided a total of 3,000 bottom sediment samples, 34 dredge hauls, 9 cores, and 169 water samples. Of these, 2,650 bottom samples, 1 core, 34 dredge hauls, and 144 water samples were obtained from the continental shelf off the west coast of central Florida, from adjacent beaches, and from rivers entering

the Gulf in this area. The remainder of the samples were obtained from other regions of the Gulf.

To obtain adequate information on the quantity and distribution of phosphate and uranium in the bottom sediments, 572 samples have been forwarded to the Trace Elements Laboratory for phosphate and uranium determinations. Approximately half of these analyses have been completed, and the others are in progress. Analyses of total salinity, phosphate, and uranium have been completed for all water samples. Micropaleontological studies of 370 bottom samples and 9 cores, undertaken to determine, in part, the age of Foraminifera that have been replaced by phosphate, are about 75 percent complete. Paleontological analyses of several phosphate-bearing rocks dredged from the sea floor are in progress. Studies of the physical properties of all samples and analyses of insoluble residues and organic carbon contents of 150 selected samples have been completed. Mineralogic and petrographic examination of representative samples is currently in progress.

Preliminary results show that the continental shelf sediments between Tarpon Springs and Fort Myers consist of: (1) detrital sands made up chiefly of quartz which are confined to the inner 20 miles of the shelf and (2) calcareous sands of organic origin which cover the outer 100 miles off the shelf area.

Available analyses and binocular examination of all samples show that higher than normal phosphate occurs only in the detrital sediments of the in-shore zone. Most of the samples from this zone contain only a trace of phosphorite, generally in the form of well-rounded ovules or as a replacement of Foraminifera or other calcareous debris. From visual comparison with chemically analyzed samples, it is estimated that most of the samples in this area contain less than 0.50 percent P_2O_5 and less than 0.0001 percent U.

However, in a few scattered areas within the detrital zone, phosphorite ovules and phosphatized Foraminifera make up an appreciable part of the bottom sediments. Chemically analyzed samples from these areas contain as much as 13.4 percent P_2O_5 and 0.0040 percent U. These areas of phosphate concentration occur in nearshore waters between Englewood and Venice, Florida and between St. Petersburg and Tarpon Springs, Florida. An area of lesser concentration is located in the southeastern part of Tampa Bay near the mouths of the Little Manatee and Alafia Rivers. The unconsolidated sediments in these areas of high phosphate concentration are either underlain by older phosphate bearing limestone and coquina or are intimately associated with adjacent outcrops of phosphatic formations on land.

No phosphorite has been detected in any of the samples from the outer zone of calcareous organic sediments. Chemically analyzed samples from this region have an average P_2O_5 content of less than 0.15 percent and a U content of less than 0.0001 percent.

The general dissemination of phosphorite in the detrital sediments of the inner zone and the absence of phosphorite in the organic sediments of the outer zone suggest that most of the phosphorite is of detrital origin and that it is being supplied by rivers draining the peninsular phosphate deposits and by adjacent phosphatic beaches.

The small areas of phosphate concentration within the inshore zone do not appear, however, to be entirely of detrital origin. Their correspondence with submarine outcrops of older phosphate bearing formations suggests that weathering of these older beds has produced much of the phosphorite in the areas of high phosphate concentration. Geologic dating of these formations must await the results of paleontological studies currently in progress.

Paleontological examinations made by O. L. Bandy of several samples containing partially phosphatized Foraminifera show that the phosphatized species are Pleistocene to Recent in age. It is possible, therefore, that replacement of Foraminifera tests by phosphate may be in progress at the present time. An attempt is being made to determine the source of the phosphate and the mechanism of replacement.

Work on this project will be suspended from June 1 to September 15 owing to the assignment of personnel to other projects during the summer field season. Laboratory work, which is now about 75 percent complete, will be finished by January 1954. Completion of the final report on the project is scheduled for June 1954.

SEARCH FOR AND GEOLOGY OF THORIUM AND MONAZITE DEPOSITS
by J. C. Olson

The project for the general study of the geology of thorium deposits has the following objectives: to determine the distribution, mineralogy, geologic relations, and economic potentialities of thorium deposits, and by geologic study of selected thorium districts to find guides to thorium that might be applicable to areas in which the element is not now known.

Work during the first part of 1953 consisted chiefly of compilation and report work. Two reports on the rare earths and thorium in the Mountain Pass district, California are near completion. Geologic and economic data on thorium occurrences and deposits are being assembled.

Monazite placer deposits, the principal source of thorium in the past and at present, are being studied by several projects. Hard-rock thorium deposits, practically unknown until a few years ago, are becoming better known through geologic studies in such districts as the Wet Mountains, Powderhorn, and St. Peters Dome, Colorado; Lemhi Pass, Idaho-Montana; Mineral Hill, Idaho; Mountain Pass, California; and Bear Lodge Mountains, Wyoming. Several of these districts are known to contain alkalic igneous rocks, and such alkalic rock provinces are promising areas for prospecting. In most of these areas the thorium occurs in thorite or a hydrated form of thorite. The hard-rock thorium deposits have promise as potential sources of thorium, but in general the recovery of thorium from the rock is more complex than from the placer monazite deposits.

As a result of brief reconnaissance studies in 1950-52, the Powderhorn district, Colorado, was selected for more detailed study in a project to begin in fiscal year 1954. The proposed investigations are described in

a separate section of this semi-annual report. Knowledge gained from a study of this district will also have application in other districts where thorite-bearing deposits occur.

The Little Johnny claims in the Powderhorn district, Colorado, were examined late in May in connection with an application for a DMEA loan. The Rare Earth Mining Company, Placerville, Colorado, has leased these claims and proposes to explore the property with a view to beneficiating the thorium-bearing rock in a mill they plan to establish in the region. Seven representative samples taken by the Geological Survey indicate the vein may contain an average of about 0.5 percent ThO_2 , which occurs in thorite and hydrothorite. Additional samples have been obtained for analysis.

General study and collation of data on the geology of thorium deposits will continue during fiscal 1954 as part of the Trace Elements Resources Unit.

Southeastern coastal plain

by Lincoln Dryden

During the last six months, the work of the project has been in 3 major phases: (1) Reconnaissance of the coastal plain from North Carolina to Florida for heavy-mineral placers likely to contain monazite. Much of this work was concentrated at the 90-100 foot level, on features supposedly associated with the Surry scarp of Pleistocene age. Although no important finds were made during this reconnaissance, the experience and knowledge gained from the Survey's work and from commercial geologists in the same type of exploration are invaluable background necessary for further work; (2) Separation of heavy-mineral suites, and sufficient study to outline the problems met, and to help in planning further work; and (3) Collections

not only from Pleistocene and Recent deposits, but from almost all the formations of the coastal plain, with particular emphasis on the Tuscaloosa formation. These collections are now being examined for monazite content; and the results of this work will be presented in a later report.

The work to date has centered largely on the part of the coastal plain underlain by Pleistocene "terraces", and within this area the search has emphasized the finding and study of large-scale sand bodies, with less attention given to the typically unsorted material of the Pleistocene deposits. In general, topography has been the only guide to such sand bodies; topographic "guides" have led to the discovery of all the producing and potential ore bodies known to the writer.

The possibility of finding monazite placers as such has been kept in mind, but the chances seem to be very small. Monazite may comprise about one percent of the heavy-mineral suite, as in several placers, but (for an unknown reason) it is seldom present in amounts much greater than this. Generally, monazite is obtained only as a by-product in operations for other minerals. The absence of monazite in certain placers has not been explained, although suggestions have been made for one case, that at Trail Ridge, Florida.

It has been found that there are two distinct and different suites of minerals in the coastal plain, at least in and south of North Carolina. One, lacking epidote, hornblende, and garnet, is characteristic of all pre-Pleistocene formations and of the higher, and presumably older parts of the Pleistocene as well. The other, containing these three common minerals, is

found in modern beaches and dunes, and in Pleistocene deposits lying below an altitude of about 50 or 60 feet. The latter suite is now being transported by numerous streams coming from the Piedmont. The causes of the change in type of suite during the Pleistocene are not clear, but a few tentative explanations have been offered in the report.

The significance of titania content of ilmenite has been discussed at some length, as this content may be a critical factor in the working or neglect of a potential ore body, and may therefore affect the production of monazite. Titania is high in almost all Florida ilmenite, but it decreases northward along the coastal plain, and upstream, toward the Piedmont. A few placers, in eastern North Carolina and one in Virginia, may have titania content higher than normal for their geographic setting.

A report in preparation includes information on the two large producing bodies at Trail Ridge and Jacksonville, Florida, and on seven placers not previously described; two of these, in Virginia, are finds made by project personnel. Three of the seven placers are reported to be in the process of development, and monazite will be recovered at all three. Monazite reserves at these seven placers are estimated roughly as between a few and ten thousand tons.

Work is now under way on the estimation of monazite content in pre-Pleistocene formations of the coastal plain. Samples are being split, separated in heavy liquid, and the suites are being made into permanent mounts. Monazite is calculated by grain counts. At present, study is being made of the possibility of achieving the same ends by use of a scintillometer on the original sample, thus speeding the operation many-fold. A report will be submitted during this summer.

A limited amount of additional rapid reconnaissance will be done in parts of Virginia, Maryland, Delaware, and New Jersey, in a search for placers similar to or larger than those already found. The project probably will be concluded by the end of the summer, and plans will have to be made to terminate it, or possibly to continue it along certain lines that will be suggested in the report being prepared.

District studies

Southeastern monazite exploration by W. C. Overstreet

Southeastern Monazite Exploration is a reconnaissance study of monazite placers in the streams of the western Piedmont in Virginia, North Carolina, South Carolina, and Georgia. The object of this study is to describe local monazite deposits, to determine geologic controls of monazite placer deposition in the southeastern Piedmont, and to evaluate placer potentialities of the area.

Work toward completion of the project can be divided into field studies, cooperative physical exploration of selected sites with the U. S. Bureau of Mines, and report writing.

Field studies include reconnaissance of the western monazite belt and the detailed study of one stream. Reconnaissance of the western monazite belt was completed December 5, 1952. Preliminary results of the reconnaissance have been reviewed in the semi-annual report preceding this one, in two memorandum reports (TEM-502 and TEM-539) recommending areas for exploration, and in a progress report which is being prepared.

Field work on the detailed study of Knob Creek, Cleveland County, N.C., was closed for the season on October 27, 1952, and was resumed in April 1953. The study is giving data on grain sizes of detrital particles available to streams, mode of transportation and deposition of detritus and relation to placers, and rate of downstream migration of monazite. From these data a fuller understanding will be had of geologic processes operative in the monazite placer district of the southeastern Piedmont.

The field phases of cooperative physical exploration of selected placers with the U. S. Bureau of Mines was completed in February 1953. Final drafting of maps of the areas drilled and preparation of reports is still under way. During the period December 1952 through May 1953 the maps and text of the Survey's part in the joint reports on the following four drilled placer sites were transmitted:

Site 1. South Muddy Creek, McDowell County, N. C.

Site 2. Silver Creek, Burke County, N. C.

Site 3. Junction of Buffalo Creek with the Broad River, Cherokee County, S. C.

Site 5. Thicketty Creek, Cherokee County, S. C.

Since December 5, 1952, collation of field data and preparation of the final report has been the chief task of the field party. Because of the large area covered by reconnaissance and the mass of data accumulated, a single final report would be unwieldy, thus for convenience in reproduction and to make the material available as rapidly as possible, the final report on reconnaissance is being prepared in sections. The sections will be presented as an integrated series of separate reports under the general title "Southeastern Monazite Exploration". Eight of the separate reports

will be divided on a basis of drainage systems; the other two will consist of introductory material, and summary and geology of the region.

Studies completed to date in the southeastern Piedmont indicate that stream deposits exceeding 10 million cubic yards in volume will contain less than one pound of monazite per cubic yard at best; the average is closer to 0.5 pound than to one pound. Only trace amounts of columbium, tantalum, and tin have been detected in the placers. Tungsten is absent. Gold will locally add a few cents per cubic yard to the value of placer ground. Deposits ranging in volume from one to five million cubic yards of alluvium can be expected to contain from one to two pounds of monazite to the cubic yard. Hundreds of small placers containing less than one million cubic yards of sediment will exceed two pounds of monazite to the cubic yard.

Unless there is interest in large-volume ground containing about 0.5 pound of monazite per cubic yard, it is recommended that no further physical exploration be undertaken in the western monazite belt.

Reconnaissance field work, which has covered 7,200 square miles of drainage in the western monazite belt, is an adequate sampling of the area. It is recommended that no further reconnaissance be undertaken in the belt.

Between June 1953 and December 1953 the field party will complete its part of the joint reports with the Bureau of Mines. Work will continue on the study of Knob Creek. Preparation of text and maps for sections of the final report will be continued.

Wet Mountains, Colorado
by Q. D. Singewald and R. A. Christman

A report entitled "Thorium investigations 1950-52, Wet Mountains, Colorado", was transmitted in April as TEI-250. The report brings together all results of the first phase of the project, i.e. preliminary reconnaissance of more than 2 dozen radioactive localities, detailed plane-table mapping of three (Haputa, Tuttle, and Greenwood), and physical exploration of one (Haputa). Conclusions, including inferred tonnage and grade at Haputa Ranch, are set forth in TEI-250.

Other accomplishments of the office season were: (1) compilation from field sheets and data of a map and of tentative geologic cross-sections of the 5-square-mile area systematically mapped last summer and (2) petrographic study of 50 thin sections, including modal analysis of 25. The petrographic study will continue as additional thin sections are returned from the laboratory. The first stage of the petrographic work has confirmed that most of the light-colored dikes are syenitic in composition and revealed that most of the dark-colored dikes are andesitic. The granites vary considerably in composition, so that some reconsideration of field units may be desirable.

The Wet Mountains thorium province has now attracted the interest of private companies. The Rare Earth Mining Company (Placerville) has leased Haputa Ranch and several other of the more promising properties.

During the current field season, systematic geologic mapping at 1:6,000 scale, accompanied by methodical search for new radioactive localities, will be continued northward from the area mapped in 1952, at least far enough to delineate and decipher the large breccia zone and the mildly

radioactive stock that were discovered toward the close of the last field season. Concurrently, field work will be extended southward from last season's area toward a group of the more promising known localities. It is hoped to determine the overall stratigraphic and structural setting needed to indicate district-wide trends of the mineralized areas and to guide geologic prospecting at individual localities.

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

The ultimate objective of this project, which will be terminated July 1, was the geologic definition of the Lemhi Pass thorium district, the evaluation of the thorium and related rare-earth reserves and of the possibilities for similar materials in the region as a whole (fig. 18). A preliminary summary report (TEM-560) on the geology and thorium deposits of the district was transmitted to the AEC in February.

The Lemhi Pass district is potentially a source for medium-grade thorite-bearing material, but it shows no evidence of significant uranium concentrations. Rare-earth metals may be considered a secondary product.

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

The period December 1, 1952 to May 31, 1953, has been spent in completion of maps, compilation of field data on maps, and laboratory study of rock specimens. The final report on the project is being completed; no further work is planned for the Lemhi Pass district.

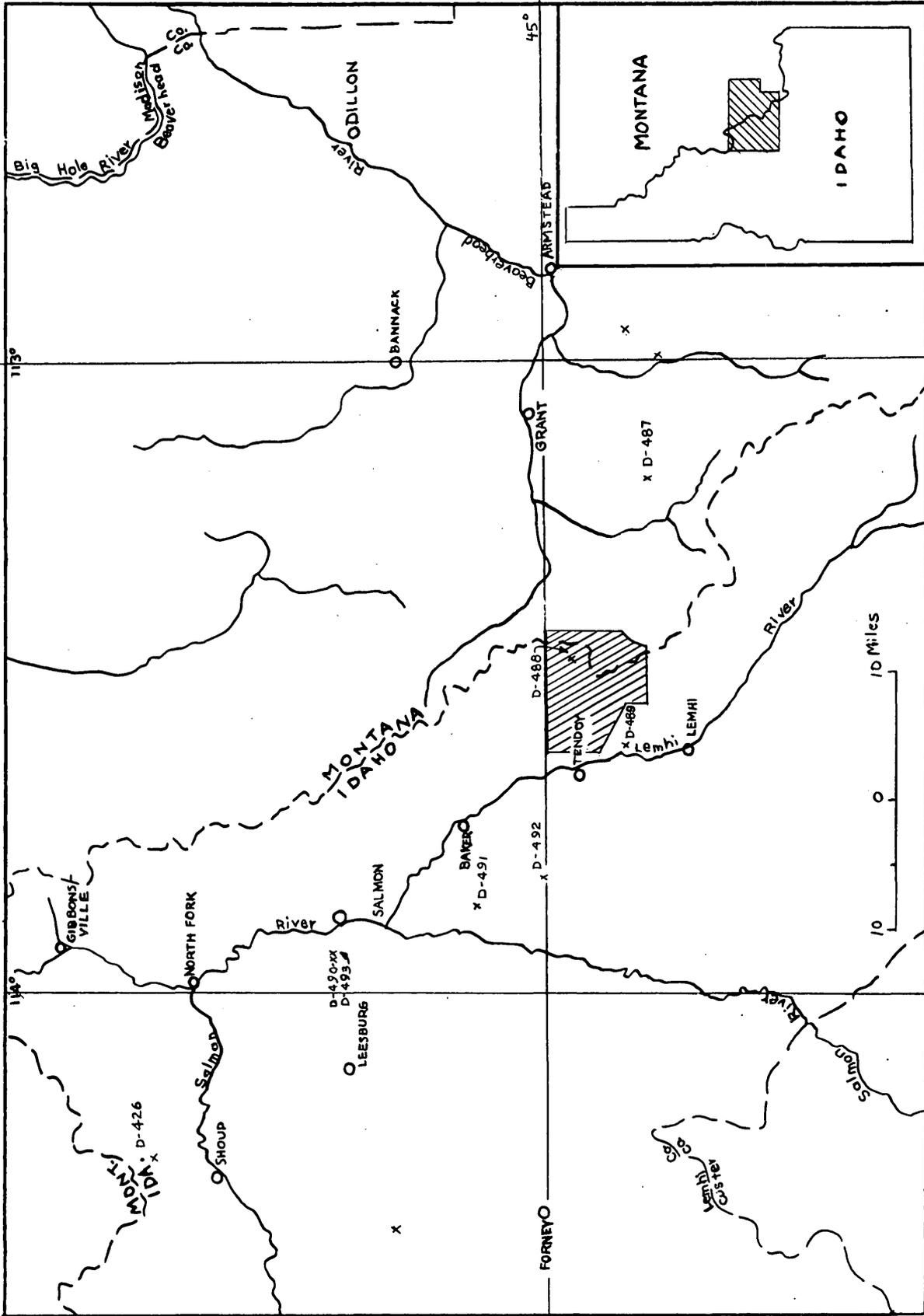


FIGURE 18.---INDEX MAPS OF LEMHI PASS AREA, IDAHO-MONTANA

(X Locality described in U. S. G. S. Preliminary Reconnaissance Report, number of report shown)

Powderhorn district, Gunnison County, Colorado
By J. C. Olson

Brief reconnaissance by Adams and Moore in 1950, Burbank in 1951 (USGS Circ. 236), and Olson in 1952 showed the presence of thorium concentrations in at least 30 deposits in the Powderhorn district. The deposits have been found in an area of about 70 square miles, in which they are spatially and probably genetically related to alkalic dike rocks such as augite syenite and shonkinite. The largest area of alkalic igneous rocks in the district is the Iron Hill complex (fig. 19), but some of the richest concentrations of thorium thus far found are 2 to 8 miles northwest of Iron Hill near areas in which smaller dikes of alkalic rocks occur.

The objectives of the Powderhorn project are to determine the distribution, size, and geologic relations of mineral deposits, particularly thorium, in the district, and to map the geology of the region in order to throw light on the origin of the deposits of rare metals and the associated rocks. In addition to thorium, other minerals, particularly columbium and rare earths, may occur in the area, as there are numerous examples in other regions of the concentration of such elements in alkalic rock provinces.

Among the areas in the district where thorium deposits are known are the vicinity of the Lot mine, 3 miles northeast of Powderhorn; the Dubois

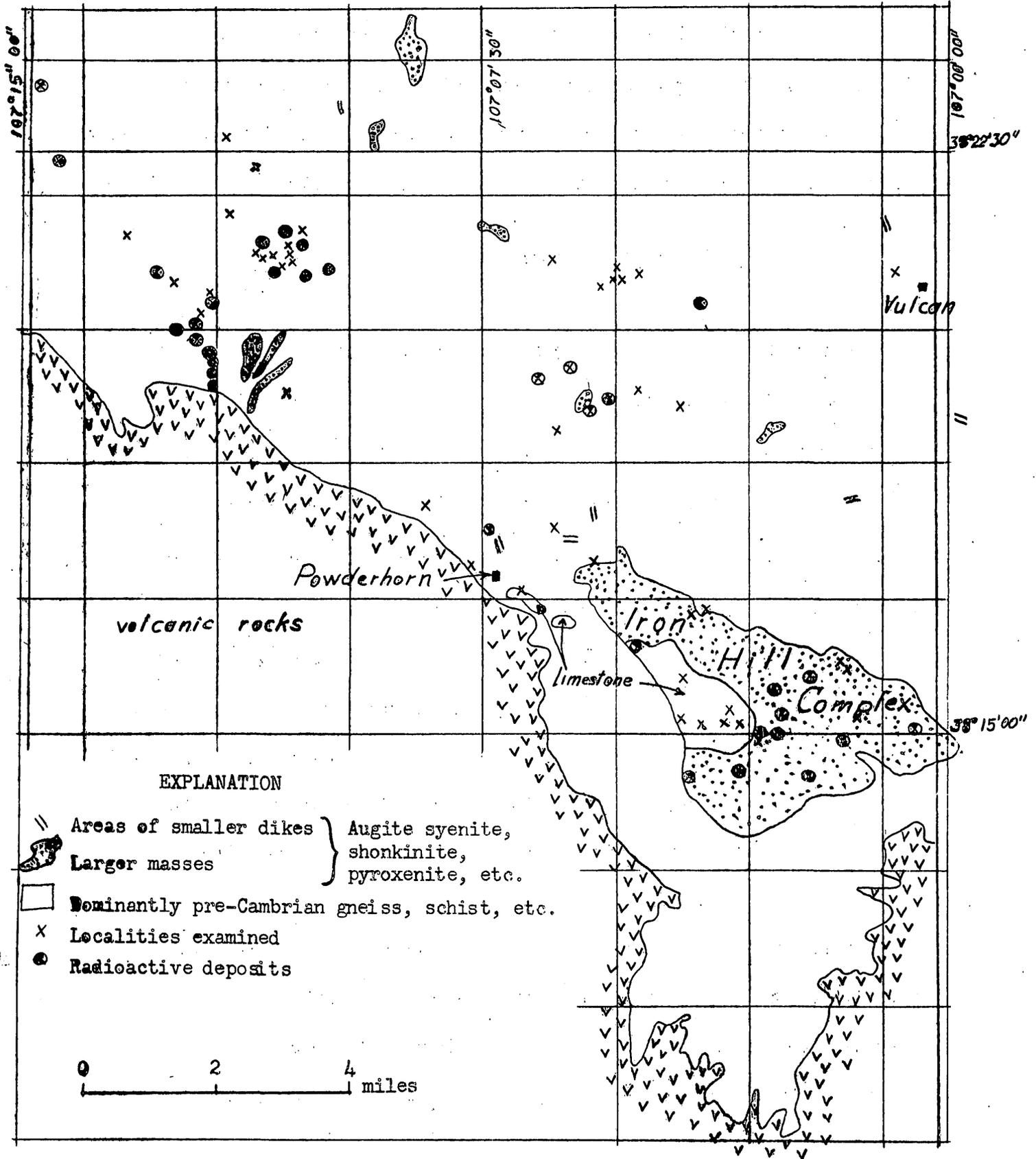


FIGURE 19.--SKETCH MAP OF POWDERHORN DISTRICT, GUNNISON COUNTY, COLORADO

area, 6 miles northwest of Powderhorn; and the area between these and Iron Hill. Completion of plane-table mapping of one of these deposits is scheduled for the summer of 1953, and the area will be studied geologically and radiometrically, sampled, and evaluated as a possible source of thorium.

Mineral Hill district, Lemhi County, Idaho
by W. N. Sharp

During the 1952 field season a significant occurrence of monazite in the Mineral Hill district, Lemhi County, Idaho, was brought to the attention of the Geological Survey (fig. 20). After identification of considerable monazite in the specimens, preliminary examinations were made of the area. The Simplot Company of Boise, Idaho, has an option on the claims and has begun development work.

The monazite deposits in the Mineral Hill district (TEM-286), are vein-like deposits, mostly within a pendant of metamorphic rocks of the pre-Cambrian Belt series about 30 miles long in the Idaho batholith of Late Cretaceous age. The minerals include calcium and iron carbonates, plagioclase feldspar, riebeckite, magnetite, rutile, epidote with monazite and allanite as accessories.

These veins are as much as 20-30 feet wide and 50 to several hundred feet long. One vein of this group crosses the metamorphic-granitic contact into the granite. Approximately 10 deposits had been located in the pendant when exploration stopped for the winter.

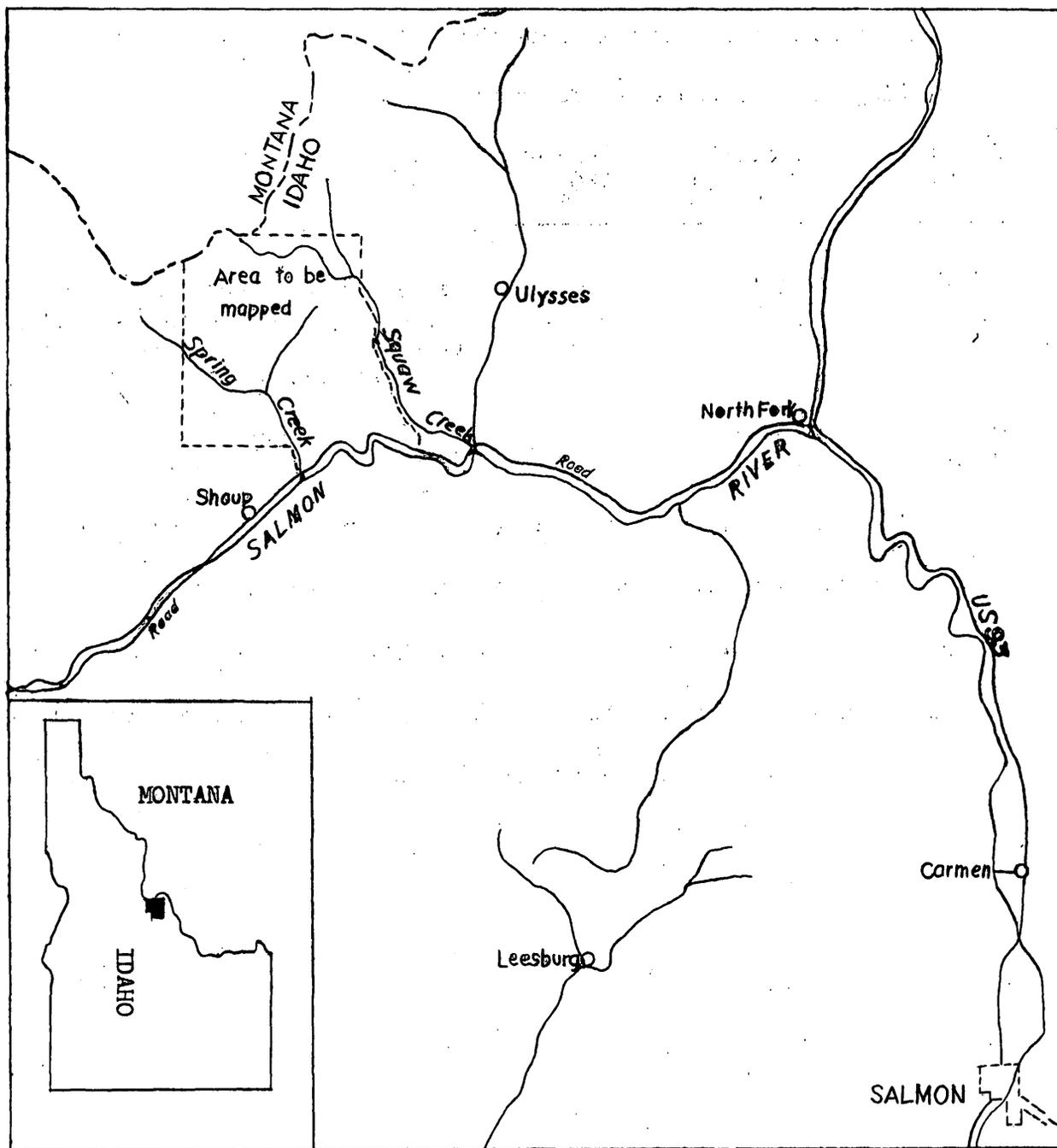


FIGURE 20 .--INDEX MAPS OF MINERAL HILL MONAZITE DISTRICT, LEMHI COUNTY, IDAHO

0 5 Miles

Five samples were analyzed from the initial discovery deposits,
Silver King claims 1 and 2, as follows:

Percent eU	Percent Re ₂ O ₃ & ThO ₂	Percent ThO ₂	
0.068	21.51	0.42	High-grade ore zone 1 foot wide.
0.040	38.04	0.31	High-grade ore zone 10 feet wide.
0.008	2.33	-	General sample across mineralized zone, 20'.
0.001	0.34	-	Sample from muck pile.
0.008	5.02	-	Sample from muck pile.

Objectives of the project are: (1) to determine the distribution of the monazite deposits in the Mineral Hill district and their relation to the pendant of metamorphic rocks and to other nearby mineral deposits, (2) to assess the economic potentialities, (3) to determine the mineralogy, structure, and origin of these unique deposits.

REGIONAL RECONNAISSANCE FOR URANIUM AND THORIUM
IN THE UNITED STATES

The objectives of the regional reconnaissance in the United States are: (1) to search for new uranium and thorium deposits based on geologic relationships; (2) to make detailed examinations of selected uranium- and thorium-bearing deposits; (3) to make reconnaissance and detailed examinations of uranium occurrences reported by the public, or requested by the AEC and Survey -- particularly requests for advice on DMEA loan applications.

The fundamental approach to objective (1) is to search for new deposits on the basis of lithologic occurrence in relation to the regional geologic picture--searches guided primarily by knowledge of geologic guides to and habits of deposits of a specific lithologic type. On this basis, most of the work is focused on reconnaissance of areas in which no trace elements investigations are in progress but which are regarded as broadly favorable for the occurrence of radioactive deposits.

This work is being conducted in the nine districts of the Survey's Mineral Deposits Branch that are divided geographically into the: Northeast, Southeast, South-Central, North-Central, Colorado-Wyoming, Southwest, Utah-Nevada, Northwest, and California districts. The activities in each of these districts during the report period are discussed below.

Northeast district
by F. A. McKeown and H. Klemic

Laboratory work during the period has not materially changed the significant conclusions expressed in TEM-551, "Preliminary report on reconnaissance for radioactive materials in the northeastern United States."

Available data indicate that the apatite-rich magnetite of the Old Bed ore deposit at Mineville, N. Y., may be a significant potential source of thorium and rare earths. However, much more adequate sampling, planned for June 1953, must be done before any legitimate evaluation can be made. Fluorapatite has been the only radioactive mineral in the tailings observed to date.

A uraniferous shear zone in Cambrian limestone at Mulligan quarry, Clinton, Hunterdon County, N. J., may warrant physical exploration. Several other radioactivity anomalies within a distance of 1,500 feet of the quarry exposure, however, indicate that mineralized rock is more widespread than apparent from the quarry alone. Moreover, although the known surface anomalies are weak, the rock below them, where weathering has not had the chance to leach uranium compounds, may be more strongly radioactive. Fluorapatite, which is probably radioactive, has been the only mineral other than normal rock-forming minerals identified in the mineralized zones. It occurs as an incrustation on joint surfaces and possibly is disseminated in the gouge of the shear zone. No study of this unusual association has yet been made.

On Marble Mountain, 2 miles north of Phillipsburg, Warren County, N. J., is a poorly exposed, perhaps discontinuous radioactive zone about 1,500 feet long. Florencite (?), with thorium substituting for cerium, and hematite have been the only radioactive minerals observed. They occur in an aphanitic, greenish-gray sericite-quartz schist that looks like a metamorphosed rhyolite. No further work in the immediate future is planned for this area.

In May, sixteen copper deposits in the Triassic Newark group and several iron deposits rich in apatite or zircon were examined in New Jersey. None was significantly radioactive. In general the copper deposits have a very low radioactivity.

Three radioactivity anomalies in Hunterdon County, N. J., and Carbon and Bucks Counties, Pa., were discovered, however, and they may prove to be significant; further work is planned for them. A sandstone quarry at Raven Rock, Hunterdon County, N. J., 4 miles north of the Stockton torbernite occurrence, contains radioactive clay. The clay has been reworked into underlying fine-grained sandstone near the top of the Stockton formation of Triassic age. It occurs as a lenticular mixture of clay galls and sandstone 10 to 15 feet in diameter and about 6 inches thick. Pyrite, gypsum, and limonite are common constituents in addition to the quartz and clay. The clay appears to be hydrothermally altered. A sample of it contains 0.28 percent eU. Two samples of the sandstone mixed with clay contain 0.034 and 0.017 percent eU.

The second occurrence of radioactive rock was discovered with a car-borne Geiger counter along U. S. Highway 611 about 1.5 miles north of Pipersville, Bucks County, Pa., about 10 miles west of the Raven Rock locality. Shale and mudstone near the top of the Triassic Lockatong formation are exposed in a roadcut. A 3-foot layer of dark-gray shaly mudstone is radioactive the extent of its outcrop, which is about 500 feet. Outcrop radiometry indicates that it may contain from 0.005 to 0.01 percent eU. Two channel samples, each one foot long, from the most radioactive part of the mudstone contained 0.027 and 0.010 percent eU.

The third radioactivity anomaly occurs along Pennsylvania Highway 45, about 2 miles east of Hometown, Carbon County. A 1-inch layer of organic-rich clay and sand on top of gravel along the shoulder of the road is

radioactive. Though field radiometry indicates it may contain about 0.02 percent eU, one sample contained only 0.006 percent eU. The area is underlain by red shale of the Mauch Chunk formation, but no outcrops were observed. Float of Pottsville conglomerate is abundant. The source of the radioactive elements, which apparently have been absorbed by the topsoil, is not known. The locality will be further examined in the near future.

Regular field work was resumed about the first of June by two field parties. Arrangements have been made with the Republic Steel Corporation at Mineville, N. Y. to examine the underground workings of the Old Bed mine. Additional samples will be collected to better evaluate Old Bed tailings as a potential source of thorium and rare earths. The Clinton, N. J. deposit will be mapped, and a rather detailed reconnaissance made of the Triassic rocks in western New Jersey and eastern Pennsylvania. The Catskill, Pocono and Pottsville formations will be examined at as many places as possible, working east and west from Mauch Chunk. In addition, many mineral deposits, which on the basis of geologic reasoning or actual reported occurrences of uranium minerals, are favorable for the presence of uranium ore, will be radiometrically examined. If time permits, field work will extend as far as southwestern Pennsylvania.

Southeast district
by H. S. Johnson

Field work began in December 1952 and has been carried on throughout the winter and spring. Brief examinations were made of different geologic environments in widely scattered localities in order to obtain sufficient information about the region to allow the rating of certain areas as favorable and worthy of more detailed investigation.

Radiometric investigations were made at thirty-three different localities; these include gold-bearing quartz veins in South Carolina and Georgia, molybdenite and tungsten-bearing veins in North Carolina, barite, zinc, red iron ore, and brown phosphate in Tennessee, and asphalt rock in Alabama. Carborne scintillometer traverses were made at several places in Alabama, Tennessee, North Carolina, Kentucky, Virginia, and West Virginia. Also, several taxpayer leads were investigated in Tennessee, Kentucky, and West Virginia. These were in Devonian, Mississippian, and Pennsylvanian rocks of the Cumberland and Allegheny Plateaus and were usually black shale or earthy limonite masses in sandstone or siltstone. No significant radioactivity was found at any of these localities.

Although no deposits of potential economic importance were found as a result of these investigations, the information obtained to date suggests that certain areas in the Southeast are worthy of further attention.

The Mississippian and Pennsylvanian rocks of the Cumberland and Allegheny Plateaus in West Virginia, Virginia, Kentucky, and Tennessee are in many ways favorable for uranium deposits of the sandstone type found in the Colorado Plateau. About the only thing that seems to be lacking is a source of uranium. In this respect, it is possible that carbonaceous shales associated with the coal beds might, under favorable conditions, release uranium to ground water or low-temperature thermal solutions. These carbonaceous shales are widespread throughout the coal-bearing formations and are estimated to contain from 0.002 to 0.004 percent eU at many places.

The Cranberry and Beech granites in Western North Carolina and East Tennessee are rather uniformly radioactive over most of their outcrop.

Samples show the rock to contain about 0.003 percent eU. Further reconnaissance in the area of Cranberry and Beech outcrop is considered desirable in the hope of finding segregations of radioactive materials.

Among other possibilities worthy of investigation are a body of syenite near Concord, North Carolina that may have associated radioactive materials, and uranium-bearing tuffs that may exist in the Carolina Slate series.

Plans for the coming field season include: (1) reconnaissance in the Triassic Basins of North Carolina and Virginia; (2) carborne scintillometer traverses in the Cumberland and Allegheny Plateaus in West Virginia, Virginia, and Kentucky; (3) investigations in the Ducktown copper district of East Tennessee; and (4) reconnaissance investigations of the gold- and copper-bearing veins of the Piedmont in Virginia, North Carolina, and South Carolina.

South-Central district
by J. W. Hill

During the period field work consisted largely of reconnaissance and examination of: (1) Ozark Dome in northern Arkansas and Missouri, (2) Tri-State mining district, (3) Central Kansas Uplift, (4) Nemaha Ridge in northern Oklahoma, (5) Ouachita Mountains and (6) Wichita Mountains in southern Oklahoma, (7) Wichita-Amarillo Uplift extending into the Texas Panhandle, (8) Permian Basin in north-central Texas, (9) Llano Uplift in central Texas and (10) Houston Salt Dome region.

Reconnaissance of these 10 areas resulted either in the finding of new deposits or in the accumulation of more information about known deposits in the following localities:

Fredericktown lead-mining region of Madison County, Missouri.

Further study of previously reported uraniferous albertite, which contains 3.79 percent U in the 20.42 percent ash (TEI-310), showed that the quantity of similar uraniferous asphaltites was below commercial importance and apparently was not genetically related to fresher, more viscous oil that occurs in small quantities as cavity fillings in the overlying Cambrian Bonneterre dolomite.

In the Picher field of Wyandotte County, Oklahoma, tar seeps from the overlying Pennsylvanian Cherokee formation into zinc mines were found to contain 0.04 percent U in the 0.073 percent ash. The quantity of tar in the seeps was reported to be below commercial significance but the mode of uranium enrichment is still under study for its geological significance.

Wichita Mountains of southwestern Oklahoma. Reconnaissance study and geological mapping of previously reported asphaltic pellets, which contain as much as 9.38 percent U in the 9.20 percent ash of unweathered pellets, (TEI-310), revealed suggestive information. In brief, the pellets are restricted to the Permian "red beds" (shale, sandstone, and argillaceous limestone) of the Hennessey, Garber, and Wellington formations or to equivalent formations along the Wichita-Amarillo Uplift occupying a distance of over 300 miles. They were found most concentrated and in larger size--up to two inches in diameter--in the flat-lying surface exposures overlying or adjacent to steeply-dipping Paleozoic limestones and dolomites along the north flank of the igneous uplift. Exposures away from the Uplift contained smaller pellets. Study of these asphaltic pellets and other oil residue revealed that they were not related to the

bedding planes. Consequently, it is probable that the oil residue in the Permian formations was deposited later than those formations and was derived from underlying or nearby Paleozoic rocks. The original source of the uranium may be related to the nearby igneous rocks--as suggested by the geographical occurrence of the deposits. Although the quantity of asphaltic pellets exposed in surface outcrops apparently can not be economically recovered today, the possibility exists that an oil trap or oil residues in greater quantities may be located in the underlying or nearby Paleozoic rocks. Study of subsurface samples is being continued to explore that possibility.

Lubbock County, Texas, of the Permian Basin area, a small deposit of radioactive caliche was sampled. Although analytical results have not been received it is estimated that the material contains 0.01 to 0.02 percent eU. Although the deposit is small, it has geological importance because apparently it owes the radioactivity enrichment to present-day stream drainage. This drainage feature may aid in locating source materials and in recognizing similar enriched deposits.

In the Houston salt domes area of the Upper Gulf Coast many oil fields contain surface and subsurface deposits of radioactive precipitates from radium-bearing brines. Initial study of this problem was begun by Garland B. Gott (TEM-27) in 1949 when he collected samples containing as much as 0.21 percent eU from the Barbers Hill Field in Chambers County, Texas. Recent information from oil companies and well-logging companies has revealed that similar precipitates also are being deposited in the following salt dome oil fields: Batson, Fannett, Goose Creek, High Island,

Homestead, Pierce Junction and Spindletop. The exact source of the radium is undetermined but if it represents a uranium concentration associated with the salt domes and related evaporites then it may be significant.

The Lee D. Uto mineral claim in Pawnee County, Oklahoma, was examined for its prospects as a DMEA venture. It is a bedded deposit of secondary uranium minerals associated with thin lignitic lenses in cupriferous sandstone of basal Permian age. Selected samples contained 16.3 percent U. Previously it has been examined by both AEC and USGS geologists (USGS PRR-51 and AEC PRR DEB-RR-419) who have discounted its present worth as a commercial venture largely on the grade of channel samples and on the lack of surface exposures of the mineralized sandstone. Nevertheless, geologically it should not be overlooked because it represents a uranium deposit in an otherwise barren area of northern Oklahoma. Also it lies over the Nemaha Ridge that underlies many oil fields producing radium-rich brines (USGS Bull. 988-E).

Evaluation of published information and available analytical data suggests that radioactive materials in the south-central states are most likely to occur associated with carbonaceous and asphaltic rocks. The fact that the region also contains the largest oil potential within the United States certainly suggests the need for an expanded study of subsurface samples. Therefore, tentative plans for fiscal 1954 include study of subsurface samples from the following areas: Wichita Mountains, Arbuckle Mountains, Nemaha Ridge, Central Basin Platform, Arkansas Tertiary intrusives, and Gulf Coastal Plain salt domes. In addition surface reconnaissance

and mapping, as needed, will be performed in the following areas: Wichita Mountains, Ouachita Mountains, Ozark Dome, Llano Uplift, and Trans-Pecos Region--all of which contain known minor deposits of uranium minerals.

North-Central district
by R. C. Vickers

During the period covered by this report, work consisted of:

(1) Mineralogical and geological study of the Huron River pitchblende occurrence, Baraga County, Michigan. (2) A DMEA examination of the Leitch & Isham uranium prospect, Dickinson County, Michigan. (3) Preliminary reconnaissance of the nepheline syenite complex, Marathon County, Wisconsin. (4) Library study of selected areas in the North-Central States where work is planned during the 1953 field season.

~~North-Central district~~
Huron River pitchblende occurrence, Baraga County, Michigan

The Huron River pitchblende occurrence was examined in August 1952, and a subsequent laboratory study of selected specimens together with an evaluation of the drilling data was undertaken (TEI-303, in preparation). The prospect was discovered in 1949 by a geologist of the Jones and Laughlin Ore Company along the East Branch of the Huron River, sec. 1, T. 51 N., R. 30 W., Baraga County, Michigan. Subsequent diamond drilling of the prospect by the Jones and Laughlin Ore Company and the Ford Motor Company disclosed only minor amounts of radioactive materials at shallow depths in the immediate vicinity of the surface showings.

The radioactive minerals, pitchblende and secondary uranium minerals, occur as very small discontinuous stringers and pods in quartz and calcite

veinlets within a low-angle shear zone that dips about 9 degrees to the southwest. The shear zone is 10 to 30 feet thick and cuts black, locally graphitic, slates of the Michigamme slate of Upper Huronian (pre-Cambrian) age.

Mineral deposition during two hypogene stages and one supergene stage was identified in polished surfaces. The first phase consisted of the introduction of quartz and minor hematite into the sheared slate. The second stage was initiated by fracturing of the quartz and deposition of calcite, pyrite, pitchblende, native copper, and tennantite, followed by bornite and chalcopyrite. The supergene stage consisted of the development of chalcocite, covellite, cuprite, and malachite. In addition to copper, uranium has been enriched near the surface by the development of secondary uranium minerals and secondary (?) pitchblende. The mineral assemblage and paragenetic sequence are similar to some of the pitchblende deposits of the Front Range, Colorado; the nickel-cobalt minerals characteristic of many of the Canadian pitchblende occurrences were not observed.

Because very little information is available concerning the geology of the area adjacent to the Huron River pitchblende occurrence, a limited amount of work will be done during the 1953 field season to determine the relation of the shear zone and associated mineralized rock to major structural features and to investigate the possibility of other occurrences or to extend the limits of the known occurrences.

The mineralogical study of the Huron River pitchblende occurrence indicates that uranium and copper minerals are closely associated. Many small occurrences of hydrothermal metallic minerals containing copper, zinc,

lead, silver, gold, bismuth, and cobalt have been reported in the literature of northern Michigan, and these localities will be examined during the 1953 field season.

**Leitch and Isham uranium claim,
Dickinson County, Michigan**

A field examination for DMEA was made of the Leitch & Isham No. 2 claim, Dickinson County, Michigan. The prospect consists of Archean (?) granite containing a 5-foot wide band of biotite schist that has been mineralized by small amounts of uranium and thorium and also has been locally altered to sericite. An unweathered sample of the most radioactive material present contained 0.016 percent eU and 0.007 percent U. No further work is planned.

Nepheline syenite complex, Marathon County, Wisconsin

During May 1953, the nepheline syenite complex and associated rocks about 6 miles northwest of Wausau, Marathon County, Wisconsin, were examined. A road traverse of part of the area, using a car-mounted Geiger counter, was made, and two large anomalies (NE $\frac{1}{4}$ NW $\frac{1}{4}$ sec. 27, T. 29 N., R. 6 E.) were found about 110 feet apart along an east-west country road. One of the anomalies was mapped in detail using a scintillometer and showed four peaks that ranged from 1.6 to 2.3 mR/hr (background 0.03 mR/hr). The anomalies have a prominent westward-trending alignment and a less prominent northward-trending alignment. There are no outcrops in the immediate vicinity, but the bedrock is believed to be greenstone (unpublished report of the Wisconsin Geological and Natural History Survey). Because of

the right-angle alignment of the anomalies, they are believed to be controlled either by a fracture system along which thoron or radon is seeping upward or by a fracture system along which there is a concentration of radioactive minerals. The anomalies are about one mile south of a thorium-bearing zircon-rich pegmatite area and may be the result of a similar thorium-bearing body beneath or in the greenstone.

The nepheline syenite complex near Wausau, Marathon County, Wisconsin, is an area of potential thorium-rare earth deposits. Zircon-bearing pegmatites containing more than 50 percent zircon have been mined to a small extent, and several rare-earth minerals (bastnaesite, eucolite, marignacite) have been reported. Because of the scarcity of outcrops, the mineral occurrences have received little attention in recent years. The small amount of work done thus far in the Wausau area has shown that radiometric traversing is effective in outlining new localities of possible economic significance. Further work in the Wausau area is planned during June 1953, the results of which will govern additional work during fiscal 1954.

Other areas

During the 1952 field season, an occurrence of autunite was found in the northern part of the Black Hills, South Dakota, in an area of Tertiary igneous activity and mineralization (TEM-559). Because little is known concerning this type of deposit in the northern Hills and because of the possibility of finding higher-grade deposits or large tonnages of lower-grade material, the one-half square mile surrounding the deposit will be mapped geologically at 1:1,200 in order to appraise the tonnage and grade

of the autunite-bearing rock, to study the geologic relationships of the occurrence in order to apply the geology to other favorable areas in the northern Hills, and to make a detailed radiometric reconnaissance in the vicinity of the occurrence to extend the limits of the autunite zone and to find new deposits.

Radiometric reconnaissance of the Lakota, Dakota, and Minnelusa formations in selected areas around the northern perimeter of the Black Hills also will be undertaken.

The occurrence of pitchblende in fractured lamprophyre dikes near Theano Point, Canada, 120 miles east of the Huron River occurrence, and abnormal radioactivity (as much as 0.014 percent U) in a lamprophyre dike about 25 miles to the southwest, suggest a possible genetic relation between the dikes and uranium deposition in the Lake Superior region. A field study of selected areas containing lamprophyre dikes in the Lake Superior region will be undertaken during the 1953 field season.

At present detailed information is being compiled concerning all of the known occurrences of radioactive minerals in northern Michigan. Detailed geological and mineralogical studies of the occurrences will be continued, to determine the origin and the factors controlling uranium deposition in that area so that other favorable areas in the Lake Superior region can be predicted.

Colorado-Wyoming district
by R. U. King and E. P. Beroni

During the second half of fiscal 1953 reconnaissance was made of the following localities and areas in Colorado and Wyoming (figs. 21 and 22):

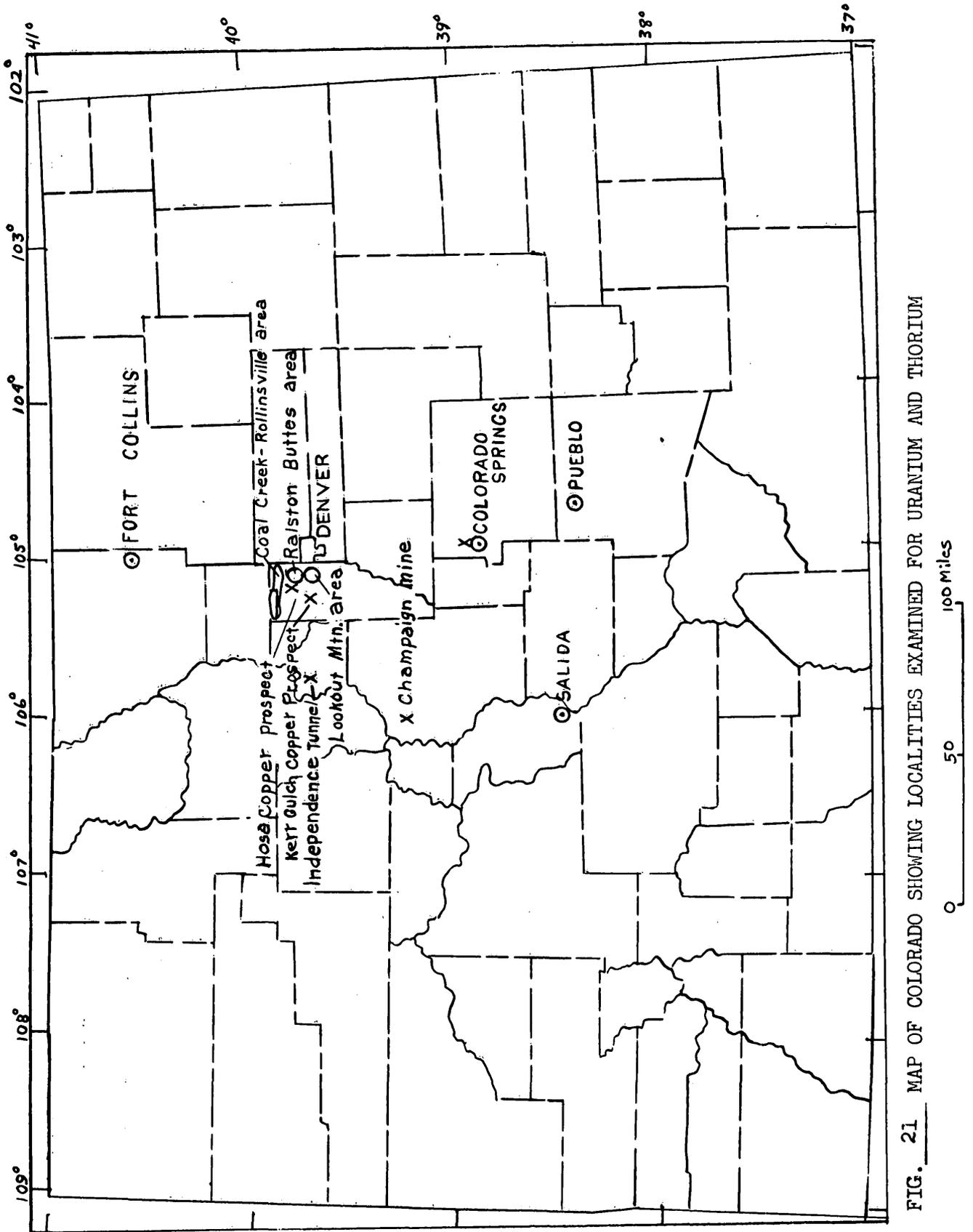


FIG. 21 MAP OF COLORADO SHOWING LOCALITIES EXAMINED FOR URANIUM AND THORIUM

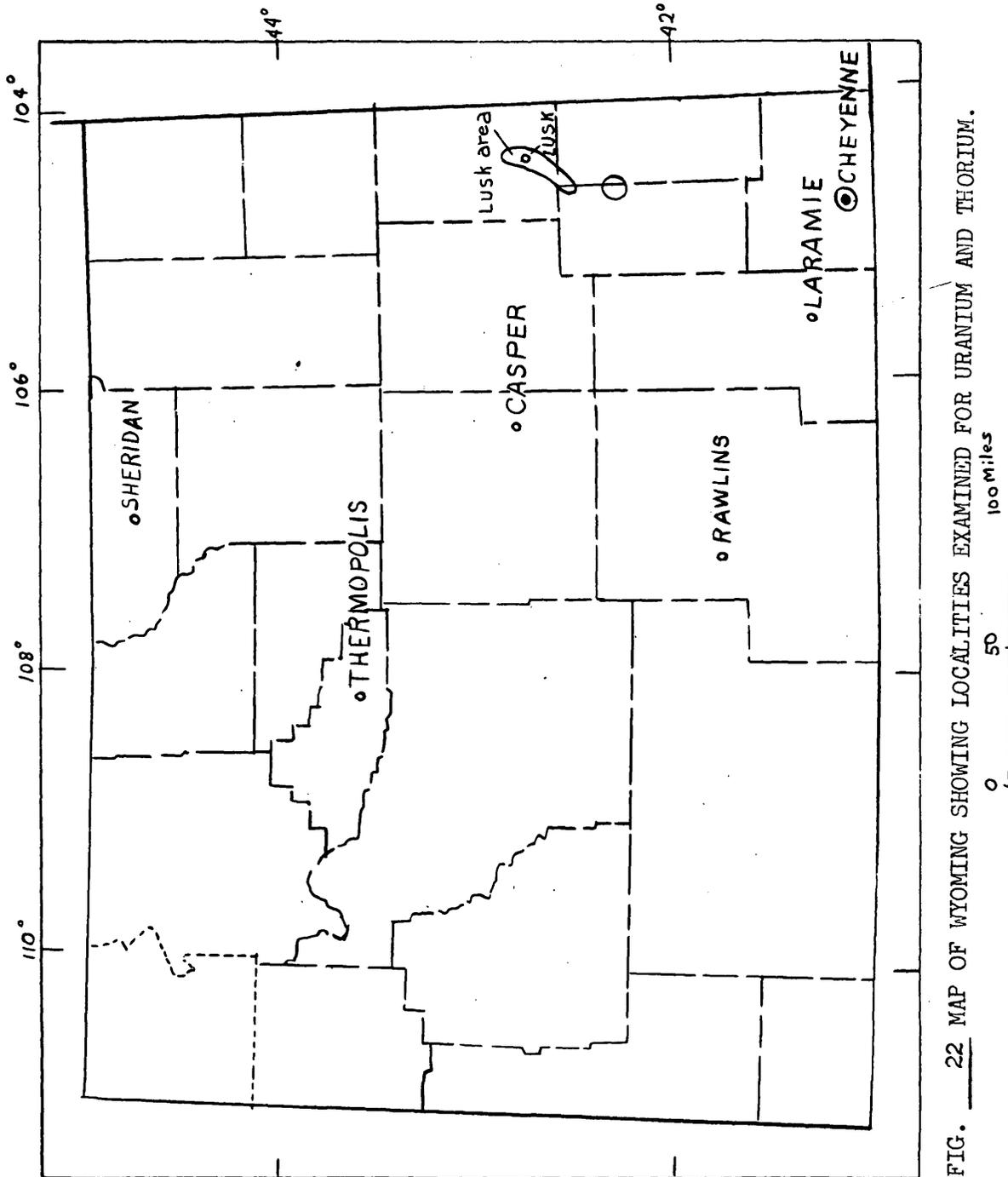


FIG. 22 MAP OF WYOMING SHOWING LOCALITIES EXAMINED FOR URANIUM AND THORIUM.

- 1) Coal Creek-Rollinsville area, Jefferson and Boulder Counties, Colorado.
- 2) Hosa copper prospect--sec. 10, T. 4 S., R. 71 W., Jefferson County, Colorado.
- 3) Kerr Gulch copper prospect--sec. 21, T. 4 S., R. 71 W., Jefferson County, Colorado.
- 4) Ralston Buttes area, Jefferson County, Colorado.
- 5) Independence tunnel, Upper Union district, Empire, Clear Creek County, Colorado.
- 6) Lookout Mountain area, Jefferson County, Colorado.
- 7) Champaign mine, Alma district, Park County, Colorado.
- 8) Blair Athol mine, Colorado Springs, El Paso County, Colorado.
- 9) Lusk area, Goshen, Platte, and Niobrara Counties, Wyoming.
- 10) Sunrise-Guernsey area, Goshen and Platte Counties, Wyoming.

Of these 10 localities, the following exhibited sufficient radioactivity to warrant further attention:

Significant radioactivity along the Boulder-Jefferson County line between Coal Creek and Rollinsville, Colorado, is associated with some of the northwesterly-trending breccia reefs. This area is less than six miles north of the known copper-uranium deposits of the Ralston Buttes-Golden Gate Canyon area (Adams, Gude, and Beroni, TEM-154). Further reconnaissance in this area is planned for the coming season.

Investigation of approximately 50 mines and prospect pits in the Ralston Buttes area, Jefferson County, Colorado, revealed four localities with significant radioactivity.

Two of these localities are within the immediate area of the known copper-uranium deposits described in TEM-154. At one outcrop in sec. 25, T. 2 S., R. 71 W., secondary copper minerals and base-metal sulfides occur in a breccia with massive quartz about 1/4 mile northeast of the Ralston Creek (Schwartz) mine. The vein material contained as much as 0.33 percent eU. At a prospect pit 75 feet to the south, fractured gneiss with secondary copper minerals contains 0.02 percent eU. These two localities may be related to the same shear zone.

At a third locality in sec. 23, T. 2 S., R. 71 W., approximately 3/4 mile northeast of the Nigger shaft (TEM-154), a quartz-carbonate breccia reef contains as much as 0.013 percent eU.

At the fourth locality, on the southeast side of Mount Tom, in sec. 9, T. 3 S., R. 71 W., vein quartz with considerable limonite associated with a fault zone contains up to 0.010 percent eU.

At the Champaign mine, Alma district, Park County, Colorado, very high concentrations of radon in the mine air were encountered, amounting to as much as 25,000 micro-micro-curies per liter. The source of the radon is unknown and no uranium-bearing minerals have been identified as yet. To attempt to determine the relationship of the radon to mineral deposits in the vicinity, geologic mapping of the mine and of the immediate surface area will be undertaken during the summer.

Secondary copper minerals with base metal sulfides at the South Copper Belt mine in sec. 1, T. 30 N., R. 64 W., Goshen County, Wyoming, contained up to 0.01 percent eU. Radioactivity was noted on the dump of the mine. The highest radioactivity is associated with fracture surfaces coated with calcite, quartz, and secondary copper minerals. The mine, consisting of approximately 300 feet of inclined shaft, will be examined to determine the distribution and source of the radioactivity.

The following reports on the results of reconnaissance work in the two-state district are in preparation: Reconnaissance investigations for uranium in the Colorado Front Range--1947-1951 (TEI-59), Reconnaissance for uranium in the Rawhide Buttes area, Goshen and Niobrara Counties, Wyoming, (TEM-293), Regional reconnaissance for radioactive materials in Colorado, 1952-1953, an interim report.

On the basis of reported uranium occurrences, metal assemblages, or regional geologic relationships, the following areas have been selected as favorable for reconnaissance investigation during the coming fiscal year:

1. Larimer County, Colorado, from Masonville and Fort Collins north to the Colorado-Wyoming boundary; chiefly an area of granitic rocks and including several small metal-mining districts, and the known uranium deposit at Prairie Divide (Cherokee mine).

2. Mining districts in Summit County, Colorado, including Dillon and Breckenridge in the southwestern part of the Colorado Front Range Mineral Belt; occurrences of uranium are reported from Dillon and Breckenridge, which are major base-metal mining districts.

3. Mining districts in the southern part of Wyoming in Albany and Carbon Counties including the Encampment district and the Pearl district, Jackson County, Colorado.

4. Casper Mountain area, Natrona County, Wyoming; carnotite is reported in this area.

5. Mining districts on the flanks of the Big Horn Mountains largely in Sheridan County, Wyoming, that have produced copper, gold, lead and manganese.

Southwest district
by R. B. Raup, Jr.

During the past 6 months 3 uranium-bearing properties were examined at the request of the DMEA:

(1) The Shattuck Denn Mining Corporation, whose property is 18 miles north of Grants, New Mexico in the northern 3/4 of sec. 24, T. 13 N., R. 10 W.,

New Mexico principal meridian, has produced well over 7,000 tons of approximately 0.18 percent uranium ore from the Recapture sandstone member of the Jurassic Morrison formation. Government assistance through DMEA for exploration of the ore horizon within the mesa behind the working face has been recommended on the basis of good geologic possibilities.

(2) The Denet Nezz property, 7 miles west of Sanastee, San Juan County, New Mexico, is also an occurrence of uranium minerals in the Recapture sandstone member of the Morrison formation. The concentration of ore minerals, however, is not sufficient to warrant exploration by drilling at this time. Samples from selected piles of "high-grade" material contained 0.034 and 0.038 percent U_3O_8 . A sample representing material in place in the favorable horizon contained only 0.015 percent U_3O_8 .

(3) An examination of the radioactive areas in the Summit mine, Wallapai district, Mohave County, Arizona, disclosed insufficient uranium to warrant exploration.

A brief examination was made of mines and prospects in the U. S. Air Force gunnery range south of the Gila River in Yuma County, Arizona. No abnormal radioactivity was found at the following properties: Fortuna, Foorman, Donaldson, Smith, Victoria, Draghi, Double Eagle, Venegas, Blue Butte, and Betty Lee. Other unnamed prospects were checked in the Gila, Copper, Tule, Tinajas Atlas, Cabeza Prieta, Wellton, and Mohawk Mountains, with negative radiometric results.

The only abnormal radioactivity found during the reconnaissance of the gunnery range is at the McMillan prospect in the north end of the Cabeza Prieta Mountains. A 6- to 18-inch fracture zone in granite adjacent to the

footwall of a pegmatite contains secondary copper and iron minerals and unidentified radioactive minerals. Inferred reserve tonnage is 300 tons of mineralized rock containing less than 0.06 percent U (sample assays have not yet been completed). Production potential at this time is considered poor.

Reconnaissance for radioactive material was made of mines and prospects in the San Carlos Apache Indian Reservation in Graham and Gila Counties, Arizona. The following properties were checked and have no significant radiometric anomalies: Bitter Springs, Tribal, Peacock, "Iron", Wylomene, and an unnamed claim. A radiometric reconnaissance of exposures of pre-Cambrian Dripping Springs quartzite is scheduled for a later date.

The airborne scintillometer survey in the Grants, New Mexico area for which a ground check was anticipated has been canceled.

Three mining districts in Arizona were checked radiometrically; no significant anomalies were discovered. The districts were: the Stanley district, Graham County; the Silver district, Yuma County; and the Castle Dome district, Yuma County. In each district a scintillation counter reconnaissance was made of most of the dumps and surface workings.

Other individual properties checked in Arizona were: Radium Hot Springs in sec. 12, T. 8 S., R. 18 W. east of Yuma in southern Yuma County where insignificant radioactivity was measured in and around the spring; Wilson Creek in the $W\frac{1}{2}$ of sec. 31, T. 8 N., R. 15 E. southeast of Young, Gila County, where radioactive minerals are concentrated on fracture planes in the pre-Cambrian Dripping Springs quartzite (samples now being assayed in Denver); and Walnut Creek in sec. 25, T. 8 N., R. 14 E.

also southeast of Young where samples from the Dripping Springs quartzite reportedly contain 0.10 and 0.20 percent U. The AEC is currently making a detailed investigation of the Dripping Springs exposures in the Young-Cherry Creek area so reserve tonnage was not estimated. Although tonnage for production from the Walnut and Wilson Creek exposures will probably be small, the potential for the Young-Cherry Creek area as a whole is promising.

Plans for the next 6 months include several reconnaissance studies of mining districts in Arizona and New Mexico. On the basis of reported occurrences of radioactive material and mineral assemblages favorable for the association of uranium or thorium minerals, the following areas have been chosen:

1. Black Rock - Big Bug - Bradshaw - Kirkland area in southern Yavapai County, Arizona. Field work in this area was begun in May 1953.
2. Hillsboro district, Sierra County, New Mexico.
3. Elizabethtown district, Colfax County, New Mexico.
4. Mammoth district, Pinal County, Arizona.
5. Silver Bell district, Pima County, Arizona.
6. Tyrone district, Grant County, New Mexico.

Providing no areas of greater promise than those listed above are discovered, plans include: 1) radiometric and geologic reconnaissance of the listed districts and 2) spot mapping of the most promising areas, mines, and prospects.

Utah-Nevada district
by A. O. Taylor

During fiscal year 1953 seven mining districts and twenty-eight mines and prospects were examined for radioactive materials. The accompanying map (fig. 23) shows the name, location, type of deposit, and presence or absence of abnormal radioactivity in the localities examined. Fifteen individual localities were found to contain radioactive deposits. The results of examination of nine of the radioactive deposits were reported in TEI-310 (pp. 233-238). The results of examination of the six new radioactive deposits are presented below.

At the Wah-Wah Lead-Zinc mine, NE $\frac{1}{4}$ of sec. 34, T. 28 S., R. 16 W., Beaver County, Utah, abnormally radioactive material was found locally on the dump. The minerals recognized are galena, marmatite, cerussite, anglesite, smithsonite, rhodochrosite, and pyrite, plus manganese and iron oxides, in Cambrian limestone. No uranium or thorium minerals were recognized. The mine is developed by a 200-foot vertical shaft and three connecting levels that were not examined because they are now inaccessible. Sample analyses have not yet been received, but it is expected that none of the samples submitted for analysis will contain more than 0.05 percent eU. Additional work is planned at this mine to outline all radioactive areas on the surface.

Abnormally radioactive Tertiary (?) rhyolite porphyry was found about 0.6 miles east of the Wah-Wah Lead-Zinc mine. The maximum radioactivity observed was four times background in unaltered rhyolite porphyry with smoky quartz phenocrysts. Altered rhyolite porphyry nearby also contained smoky

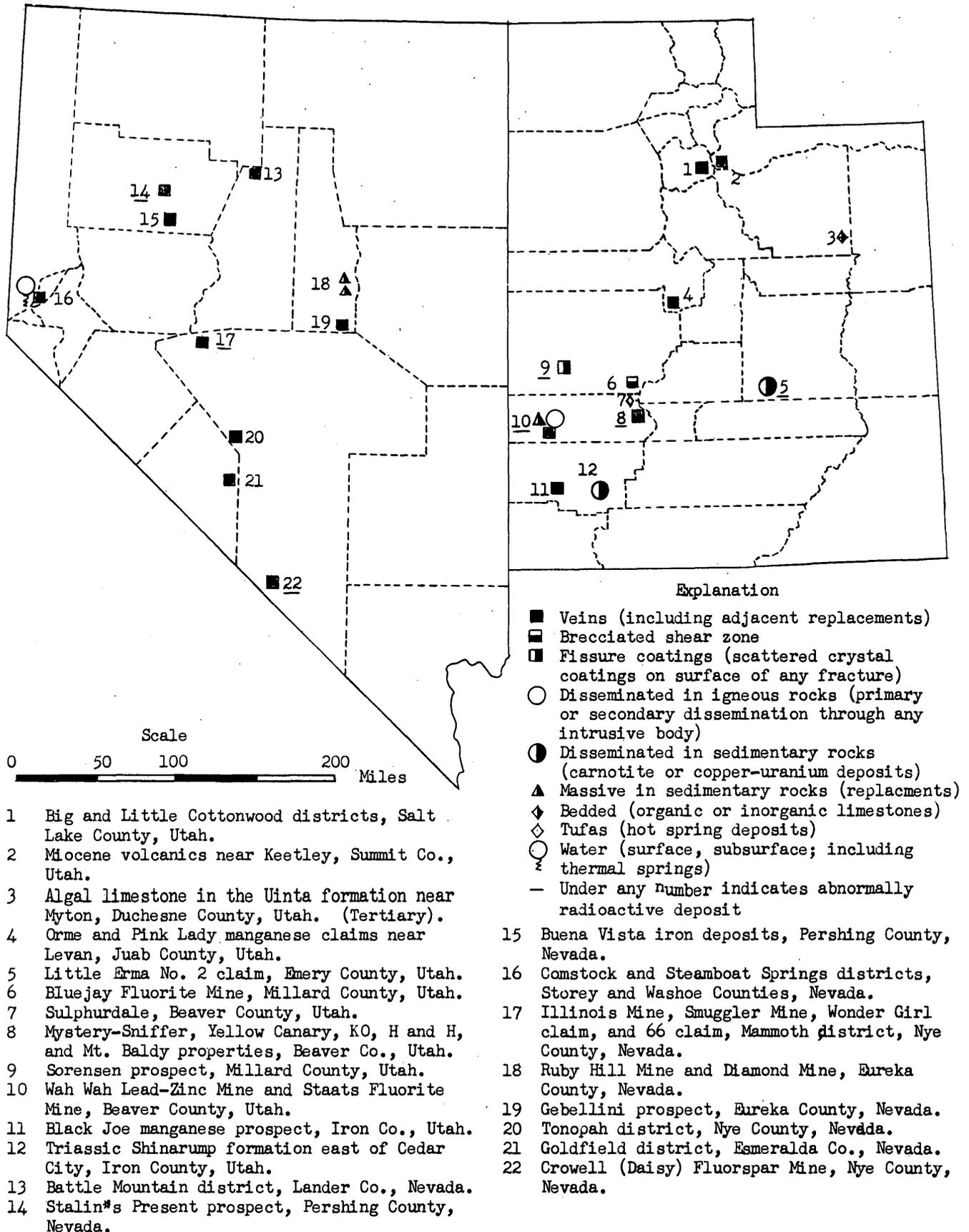


Fig. 23—Index map of Utah and Nevada showing localities examined for radioactive materials during fiscal year 1953.

quartz phenocrysts but did not register above background. The amount of abnormally radioactive rhyolite porphyry is certainly very large but its grade is very low, probably less than 0.005 percent eU. Part or all of the radioactivity may be due to thorium. Samples were collected and submitted for analysis but results are not available for inclusion in this report. Reconnaissance-type geologic and radiometric mapping is planned to determine the size and grade of the deposit and to investigate the possibility of radioactive deposits occurring at the contact of the rhyolite porphyry and Cambrian limestone.

The Illinois mine, the Smuggler mine, the Wonder Girl claim and the 66 claim in the Mammoth mining district, Nye County, Nevada, are located about twelve miles north of Gabbs, in T. 13 N., R. 37 E., near and at the contact of a granite stock and Paleozoic limestone. The Wonder Girl claim and the 66 claim each have a uranium deposit in a fractured zone in granite. The granite is sericitized and contains small amounts of lead, copper and iron minerals. No uranium minerals were observed at the Wonder Girl claim, but at the 66 claim one sample of sericitized granite with a thin layer of a black, highly radioactive mineral, probably pitchblende, was found. No analytical results are available, but it is expected that the uranium content will not be higher than 0.05 percent. These two deposits have no immediate potential for the production of uranium ores and they have little future potential unless the grade is notably greater below the zone of weathering and leaching. More work is planned in the area of the granite stock to determine if other radioactive deposits can be found and if the known deposits can be traced along their strike projections.

The Smuggler mine is at the contact of granite and limestone. A small amount of slightly radioactive material is on the dump and is said to have come from the bottom of an inaccessible shaft 90 feet deep. About 750 feet of adit workings were examined radiometrically but no abnormal radioactivity was found.

The Illinois mine produced important quantities of lead and silver until 1922. It is about 500 feet east of the Smuggler mine. No abnormal radioactivity was found on the surface outcrops or old dumps of this mine.

At the Crowell Fluorspar mine, about 5 miles east of Beatty, Nye County, Nevada, radioactivity as much as five times background was found in an altered igneous rock on the dump. The dark-purple fluorite ore of this mine is faintly radioactive, about 2 times background. No analytical data are available on samples collected but the highest grade material will not contain more than 0.02 percent eU. The deposit has no apparent potential for the production of radioactive materials.

Work planned for fiscal year 1954 includes reconnaissance radiometric examination of the following localities: Needle Mountains, and Mineral Mountains, Beaver Co., Utah; Goodsprings district, and Muddy Mountains, Clark Co., Nevada; Drum Mountains, Juab Co., Utah; Humboldt Mountains, Pershing Co., Nevada; Deep Creek Mountains, Tooele Co., Utah; Sloan district, and Sutor district, Clark Co., Nevada; Buffalo district, Churchill Co., Nevada; Atlantic district, Lincoln Co., Nevada; Yerington area, Lyon Co., Nevada; Toquima range, Nye Co., Nevada; Antelope district, Pershing Co., Nevada; Crescent district, Clark Co., Nevada. The selection of these localities is based on known occurrences of radioactive materials

and on the occurrence of mineral suites known to be associated with uranium or thorium elsewhere in the world. Additional work is planned in Beaver County, Utah, in the Tushar Mountains, Mineral Mountains, and Wah Wah Mountains. The work planned will consist of reconnaissance-type geologic mapping in the vicinity of the known fluorite-uranium deposits and radiometric reconnaissance in areas considered geologically favorable for the occurrence of new deposits.

Northwest district
by F. C. Armstrong

Central Idaho placer deposits

The most important development in the Northwest during the last six months has been the growing importance of the central Idaho placer deposits as a possible source of radioactive minerals. It is reported the Porter Brothers intend to move into Bear Valley, Valley County, Idaho, two bucket-line dredges capable of handling together 10,000 cubic yards a day. The uranium occurs in samarskite, euxenite and other "radioactive blacks". Porter Brothers is reported to have worked out the metallurgy of these minerals and to be able to recover both the uranium and columbium.

J. R. Simplot Company expects to start work this summer on a columbite placer deposit in Elmore County, Idaho. This deposit could contain "radioactive blacks" and will be checked for them.

Cosumnes Gold Dredging Company has stopped work at both their Paddy Flat and White Hawk Basin properties. The Paddy Flat property did not contain enough monazite or "radioactive blacks" to be worked.

at a profit. The gravels in White Hawk Basin proved to be disappointingly thin and to have a low monazite content. There are indications, however, that the gravels of White Hawk Basin contain "radioactive blacks" and because the Basin is located just west of Bear Valley, Porter Brothers may be interested also in the White Hawk Basin deposits.

Crescent mine, Shoshone County, Idaho

Unwatering of the Crescent shaft has permitted radiometric examination of the accessible part (only 110 feet) of the Alhambra fault-vein on the 400-foot level. No abnormal radioactivity was detected. The 1200-foot level is unwatered but has not yet been examined because of bad air. Examination of the core of old diamond drill hole No. 10 has shown the presence of 4 inches of abnormal radioactivity, red alteration, and pitchblende(?) at 73 feet in the hole. This intersection is 55 feet vertically below the pitchblende occurrence in the Alhambra fault-vein on the Hooper Tunnel level. Core recovery near the vein was only 4 inches from 8 feet of hole.

Lemhi Pass thorium deposits

Work at the Last Chance thorium deposit, Beaverhead County, Montana, has been stopped at the request of the company. Semiquantitative spectrochemical analyses of drill core samples show less than one percent thorium. The highest equivalent uranium content was 2.4 feet that assayed 0.068 percent. No more work is contemplated at this property.

At the Defense Metals thorium property, Lemhi County, Idaho, drifting on the vein was started in May 1953. The drift will explore the most radioactive part of the vein 100 feet below the outcrop. Reliable thorium assays are not yet available on samples taken last fall.

Examination of the Merikay (Railway Dike) pegmatite deposit, Stevens County, Washington indicates that it does not contain enough radioactive minerals to be worked for them alone. Recent work indicates that the deposit probably does not contain enough beryl to be worked.

Shaft sinking is in progress at the Western States Copper Corporation property, King County, Washington. Brannerite occurs with the ore but at present it appears unlikely that this property will become a source of radioactive materials.

Plans

The central Idaho placer deposits south of the Salmon River will be examined further in an effort to find more deposits of "radioactive blacks". Placer deposits in central Idaho north of the Salmon River will be investigated. DMEA applications on placer deposits south of the Salmon River will be investigated.

The radioactive occurrences at the Merikay pegmatite and Western States copper deposits will be examined as work at these properties progresses. The Idaho-Montana fluorite deposits will be examined for radioactivity. Work has been resumed at the Garm-Lamoreaux mine, Lemhi County, Idaho; the new workings will be examined for radioactive materials. The Quartzburg district, Grant County, Oregon, will be radiometrically examined. And work in the Coeur d'Alene district, particularly at the Crescent mine, will be followed.

California district

by G. W. Walker

Work completed during this period included (1) reconnaissance examination of 32 mine properties, prospects, and claims, and intervening radiometric tests of bedrock exposures and placer deposits in eastern Imperial County, (2) examination and evaluation of 2 properties for DMEA, (3) evaluation of data collected on 6 properties by geologists of the Mineral Deposits Branch office in San Francisco, and (4) compilation of data and preparation of an interim summary report concerning occurrences of radioactive materials in California.

Field work consisted of a reconnaissance investigation of mineralized areas, placer deposits, and exposures of bedrock in eastern Imperial County. Thirty-two mine properties and prospects east and southeast of the Salton Sea (Imperial and Riverside Counties) were tested radiometrically. Placer concentrates of dark minerals, which are common in many of the dry washes of the region, were tested radiometrically; selected samples of the placer concentrates were further concentrated and checked for radioactive minerals in the laboratory. Various types of bedrock exposures, including schist, gneiss, quartzite, plutonic crystalline rocks and Tertiary volcanic rocks, also were checked for anomalous gamma-ray activity.

The Easter Sunday group of claims in the Mountain Pass district, San Bernardino County, was examined at the request of DMEA. The examination, made in company with D. R. Shawe, of the Geological Survey, was directed principally toward an evaluation of the property as a potential source of rare earths. Thorium, principally in thorite, also occurs on the claims; according to Shawe, who previously mapped and studied parts of the area,

the thorium content is low and is erratically distributed. A brief re-examination of the Rosamond Prospect, Kern County, Calif., was made for DMEA.

Evaluation of data collected during these field examinations suggests that none of the properties or areas constitute potential sources of thorium or uranium. In eastern Imperial County only one of the 32 mine properties and prospects examined showed significant anomalous radioactivity. The property, which had previously been examined in April 1952 (PRR D-423), contains small amounts of autunite and carnotite in hydrothermally altered quartz-mica schist and felsic intrusives. Placer concentrates contain insignificant amounts of radioactive minerals, and the bedrocks exposed in the region are virtually non-radioactive. Examination of the two properties for the DMEA uncovered no new or additional evidence that would warrant changes in the earlier evaluations of these properties as potential sources of thorium or uranium.

During this period reports were prepared and/or transmitted on the following properties or areas: a DMEA report on the Easter Sunday group of claims, a DMEA report on the Rosamond prospect, and a TE report on regional reconnaissance in eastern Imperial County. An interim summary report on the known occurrences of radioactive minerals in California is in preparation, and should be completed about August.

Tentative plans for the next period include regional reconnaissance investigations in the Modoc Plateau area, Modoc and Lassen Counties, and in the Gavalan Mesa area, Monterey County. Also collections of ore, mineral, and rock specimens in collections at the California State Division of Mines and at the University of California are to be checked for anomalous gamma-ray activity.

REGIONAL RECONNAISSANCE FOR URANIUM

AND THORIUM IN ALASKA

By Helmuth Wedow

Introduction

The chief objective of the regional reconnaissance program in Alaska has been the search for high-grade uranium ores. In spite of the fact that many favorable districts, areas, and prospects were examined in the period 1945-52, only a few minor occurrences of uranium and thorium minerals were found. This failure to discover significant uraniferous deposits is attributed mainly to the fact that essentially 50 percent of the geology of Alaska is unknown, even on a reconnaissance scale, rather than to the possibility that no commercial uranium deposit occurs in the Territory. However, because no significant deposit has been found to date it is planned to redirect the Alaskan reconnaissance studies into such other channels as: (1) more encouragement and aid to prospectors through the maintenance of preliminary assay service at Fairbanks and the publication of as much information on uranium in Alaska as possible, the latter with particular reference to areas possibly favorable on the basis of what is known of regional geology and radioactivity; and (2) review of techniques for prospecting for uranium, particularly radiometric and geochemical, to determine the precise modifications and methods of application necessary for Arctic and sub-Arctic reconnaissance. In view of the fact that much of Alaska is remote and of difficult access and hence requires the use of air travel, every effort should be made to encourage private prospectors to use airborne techniques. Such encouragement can well be made through the development of a relatively

portable recording scintillometer and the publication of the procedures in the use of such an instrument and the interpretation of the data obtained. The redirection of Alaskan studies in the future will lead to a reduction in the overall annual cost of the program unless, of course, significant occurrences of uraniferous materials, requiring detailed geologic study and physical exploration, are discovered.

Reports on results of reconnaissance in 1952

No field work on radioactive materials was conducted in Alaska during the period and the entire time was devoted to the preparation of reports on field work of previous seasons and preparation for the 1953 field season.

In December 1952 preliminary results of Alaskan reconnaissance in 1952 were transmitted as report TEM-552, "Preliminary summary of reconnaissance for uranium and thorium in Alaska, 1952", by Helmuth Wedow, Jr. and others. Final reports on the 1952 field work will be transmitted in the near future in reports as follows:

- TEI-291, "Reconnaissance for radioactive deposits in selected areas of the lower Yukon-Kuskokwim region, Alaska, 1952", by W. S. West.
C-238
- TEI-292, "Reconnaissance for radioactive deposits in selected areas of eastern Alaska, 1952", by A. E. Nelson, W. S. West, and J. J. Matzko. C-340
- TEI-293, "Reconnaissance for radioactive deposits in selected areas of southeastern Alaska, 1952", by J. R. Houston, R. S. Velikanje, R. G. Bates, and Helmuth Wedow, Jr.
Archives

Plans for June 1 - November 30, 1953

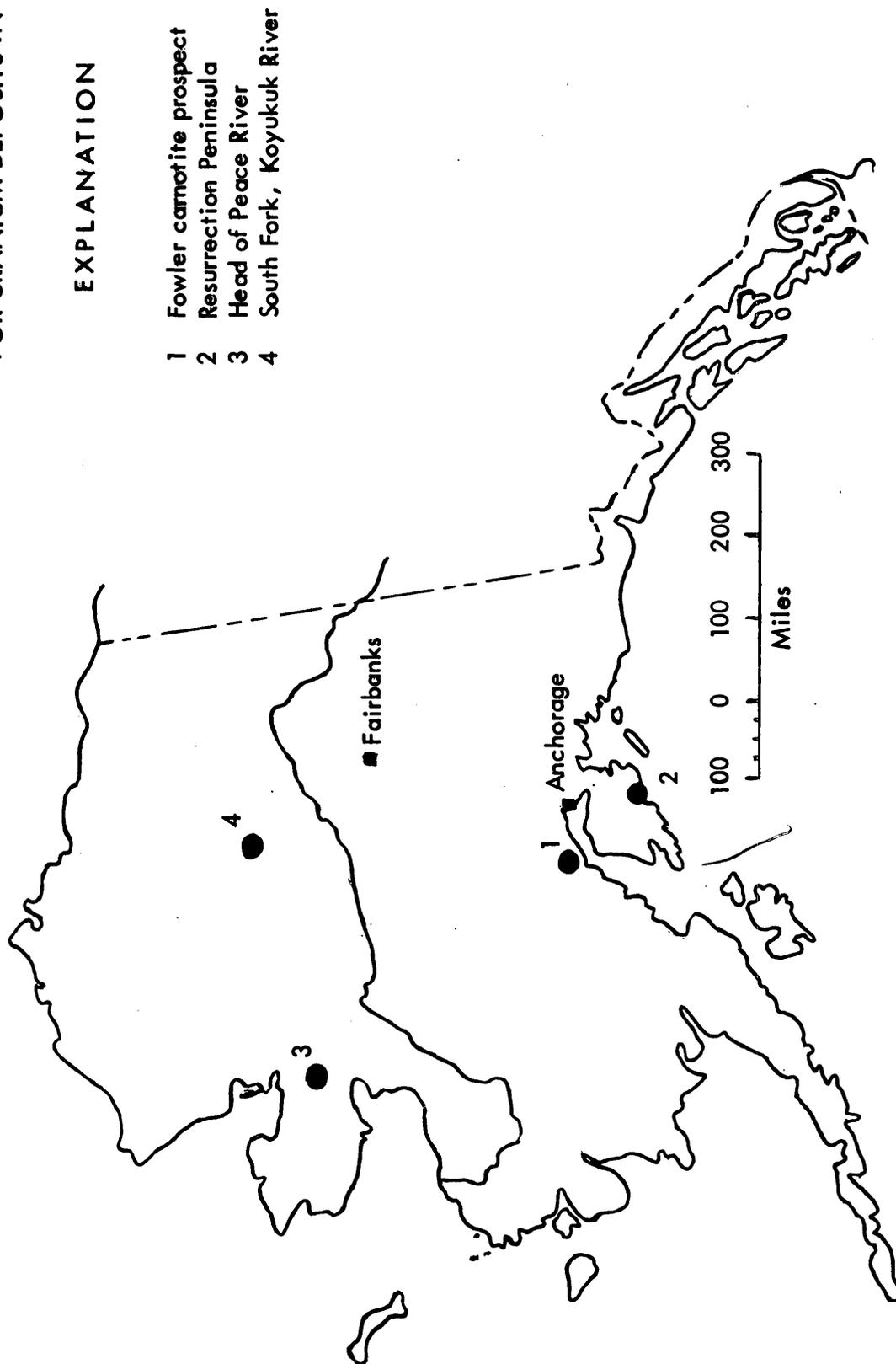
In the semi-annual period June 1 - November 30, 1953 the activities on the Alaskan reconnaissance program will consist of: (1) the field examination of several known or reported occurrences of uranium minerals, (2) the

maintenance of the Radioactivity Testing Laboratory at the University of Alaska near Fairbanks to provide assay and preliminary mineral identification service for the public and Survey field parties, and (3) the completion of reports on previous years' investigations.

The reconnaissance studies will include: (1) the examination of the "Fowler carnotite prospect" on Nikolai Creek, northwest of Tyonek (TEM-552, pp. 20-23), and (2) a reported occurrence of carnotite on Resurrection Peninsula near Seward (TEM-552, pp. 34, 35), (3) the search for bedrock sources of uranothorianite and associated sulfide minerals in placers (a) at the head of the Peace River in the eastern Seward Peninsula (TEM-355), and (b) on the South Fork of the Koyukuk River in east-central Alaska (TEM-552, pp. 12-14). The locations of these occurrences are shown on figure 24. If the search for and initial field appraisal of the Fowler prospect on Nikolai Creek in June is successful and indicates the presence of significant uranium deposits, it is anticipated that the reconnaissance party will remain in that area for the remainder of the season. Work on the other uranium occurrences mentioned above will then be postponed until the 1954 field season.

Because the location of the Fowler prospect is in the northern part of the Air Force's Tyonek aerial gunnery and bombing range field work there will, of necessity, be coordinated with Air Force activities in the range area. It is planned to initiate the reconnaissance in the Nikolai Creek area with an airborne radioactivity survey using a civilian helicopter. Air support of the field party in the Military reservation by the Air Force is being requested, particularly in case the party remains there for the entire season.

Figure 24.--LOCALITIES IN ALASKA TO BE EXAMINED FOR URANIUM DEPOSITS IN 1953



ANALYTICAL SERVICE AND RESEARCH ON METHODS

Service
by Jack Rowe

Tabular data pertaining to routine analytical work completed during the period December through May are listed below.

Table 5.--Analytical work and sample inventory, Dec. 1952-May 1953

Project or material	Chemical determinations		Spectrographic determinations	Radio-metric determinations	Samples received	Samples on hand at end of May
	Uranium	Other				
<u>Washington Laboratory</u>						
SE phosphates	2524	688	14893	6237	6705	10189
AEC, New York	167	29	6222	22	316	75
Lignites, coals, shales	2908	953	4964	2961	1927	1284
NW phosphates	11	11	68	32	42	63
Sea waters and bottoms	33	-	272	-	380	341
Geochemistry of U	646	529	23139	125	151	128
Miscellaneous	226	325	10157	164	342	153
Uranium in waters	55	-	-	-	20	18
SE monazites	-	-	1836	5	1500	2087
Totals	6570	2535	61551	9546	11383	14338
<u>Denver Laboratory</u>						
Colorado Plateau	1225	3646	5236	2523	3091	1100
Plants and soils	1635	2664	4320	3	499	121
Oil well drilling	21	52	1377	438	1393	1317
SE phosphates	194	-	-	713	151	626
AEC samples	1351	618	6549	1637	2385	1011
Reconnaissance	1057	2672	32541	1473	2496	2055
Fuels	213	166	705	159	283	221
Miscellaneous	98	154	4989	210	162	138
Totals	5794	9972	55717	7156	10460	6589
Grand Totals	12364	12504	117268	16702	21843	20927

Research

Radiometry

Thorium analysis, by W. R. Champion, F. J. Flanagan and F. E. Senftle

The experimental program for measuring thorium by a photographic technique has been temporarily suspended due to the lack of personnel, but it is hoped it can again be activated this summer by addition of some summer help. The theoretical calculations have continued, however, and tables for calculating radioactive equilibrium and photographic alpha stars have completed. A report on this has been written by Flanagan and Senftle for publication.

The emanation method for measuring thorium in zircon has also been curtailed due to lack of personnel but some work has continued on this problem. A new furnace for heating the zircon has been designed and the problem of high temperature oxidation of the filament heater has been circumvented. Qualitative results only have been obtained to date.

Spectrography
by C. L. Waring

During the period, progress in spectrographic development and research was limited, due to the heavy load of test requests. A total of 117,268 qualitative, semiquantitative and quantitative determinations were completed.

The automatic scanning of semiquantitative plates has shown some progress. The method is being set up to scan automatically the spectrograms of lignite ash samples, and is expected to cover numerous types of

simple spectrograms. The method was designed to reduce eye fatigue and human error.

The paper entitled "Method for determination of small amounts of rare earths and thorium in phosphate rocks," by C. L. Waring and H. Mela, was published in Analytical Chemistry, Vol. 25, pages 432-435, (1953). "The spectrographic identification of mineral grains," by J. N. Stich was published as Geological Survey Circular 234. "A spectrographic method for determining trace amounts of lead in zircon," by C. L. Waring and H. Worthing has been accepted for publication in American Mineralogist. "A semiquantitative spectrographic method for the analysis of minerals, rocks, and ores," by C. L. Waring and C. S. Annell has been accepted for publication in Analytical Chemistry. "A second locality of novacekite," by T. Stern and C. S. Annell has been completed. The abstract is as follows: "Novacekite, $Mg(UO_2)_2(AsO_4)_2 \cdot nH_2O$, was identified from the Laguna Reservation, New Mexico, by means of spectrographic, X-ray, and optical studies."

The evaluation of the quality of certain spectrographic analyses, both in Washington and Denver, was continued by the staffs of the spectrography projects with the aid of the Washington chemists, and the differences observed were not considered to be significant.

Work will be continued to improve the quality of the analyses on our qualitative, semiquantitative and quantitative methods and to develop new methods as suggested by requests received in the laboratory.

Chemistry

Stabilities of dilute solutions of U, Th, and Pb on storage in glass and polyethylene bottles, by R. G. Milkey

A final report describing the results of this study is being prepared. With the completion of this report the project will be terminated.

New transmission fluorimeter for solutions

The second model of a transmission fluorimeter for solutions was built and used about one month. (The first model was a cardboard model, and was mentioned in the last semi-annual report). In this instrument, as in other transmission fluorimeters, the exciting light is above the sample, and the phototube directly below the sample. The sample slide includes a fluorescent glass standard which provides a convenient means for setting the instrument to a standard sensitivity. The measuring unit consists of a 1P21 photomultiplier tube used in conjunction with a commercial regulated high voltage supply and an ultra sensitive D. C. microammeter. Highly reproducible measurements may be obtained with this instrument.

In designing the new fluorimeter, a transmission type was selected because it is more flexible and a better research tool than the conventional type which measures the fluorescence at an angle of 90° from the path of the exciting light. With a transmission fluorimeter one can study fluorescence in relation to the depth of the solution, and determine the dependence of the fluorescence measured on the absorption of the exciting light and emitted light by the solution. With an instrument of this type, one should be able to determine exactly the optimum concentrations of reagents and depth of solution which will give the greatest sensitivity.

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

Laboratory work on this project has been completed. The method, as developed, effectively eliminates the interference of arsenic, germanium and silicon which are the major sources of error in determining micro quantities of phosphorus.

The pressure of current work has delayed the preparation of a report on this method.

Zirconia dishes in fluorimetric uranium analysis, by F. Cuttitta and F. S. Grimaldi

Zirconia dishes have been obtained as a possible substitute for platinum containers for use in the preparation of the fluorescing melts in uranium analyses. It is hoped that the quenching interference of platinum can be eliminated by the use of zirconia dishes.

The molded zirconia dishes are too rough for use as received and it will be necessary to have the inside of the dishes machined to a smooth surface before use. This work will be done and tests of the dishes will be made in the near future.

A study of the flame photometric determination of calcium in "leached zone" samples, by Lillian Jenkins.

We are now determining calcium in leached zone samples by the permanganate titration of calcium oxalate. It was thought that much time could be saved in determining calcium if a simple and accurate method could be developed using the flame photometer.

The first problem was to overcome the interference of P_2O_5 . It was found that the amount of depression of the intensity of the calcium

line caused by the P_2O_5 , remained constant from 100 ppm to 500 ppm P_2O_5 . If 100 ppm P_2O_5 were added to standards, accurate readings could be obtained.

The next step was to overcome the interference of Al_2O_3 . $ZrOCl_2$ was added to precipitate $Zr(HPO_4)_2$ and then NH_4OH added to precipitate iron and aluminum, leaving $CaCl_2$ in solution. The supernatant solution was atomized into flame photometer, but it was found that ammonium salts caused serious interference. Removal of ammonium salts would be time consuming.

An attempt was then made to overcome the interfering effect of aluminum by adding $MgCl_2$ (a method proposed in the literature). There was some indication that this might be the correct approach, but we could not spare the time for a prolonged study. It is hoped that this work can be continued at a later date.

It is planned to purchase a multiplier attachment for the instrument which will enable the use of fine slit widths. It is also proposed to study the use of strontium salts which have been recommended by Dean for minimizing the interference of aluminum.

Note on the determination of selenium in rocks which contain organic matter, by E. J. Hackney

The standard method for determining selenium is difficult to apply to rocks containing much organic matter. Wet oxidation methods do not destroy all the organic matter in such samples and also are accompanied by much foaming and spattering.

It was found that sintering the sample with a mixture of zinc oxide, magnesium oxide and sodium carbonate similar to Eschka's mixture removed organic matter very effectively with a minimum of effort.

This study is concluded.

Determination of aluminum in leached zone samples, by M. Delevaux

The aluminum content of "leached zone" samples is much higher than that in phosphate rocks. It was thought desirable to investigate several methods for large amounts of aluminum to determine their applicability to such samples. A method was desired which was comparable to those in general use by industrial laboratories and which was both accurate and rapid.

An attempt to modify the Bureau of Standards procedure for aluminum in phosphate rocks was made to make it more rapid; this resulted in aluminum phosphate precipitates which were heavily contaminated with iron.

Next, an amyloacetate extraction of a cupferron precipitation followed by the precipitation of aluminum as the quinolate was tried, but the excess amyloacetate interfered with the quinolate precipitation.

Another method tried was precipitation of aluminum quinolate in the filtrate from a cupferron precipitation of interfering elements (with no destruction of excess cupferron). The aluminum was not completely recovered.

It was finally decided to use the Bureau of Standards Method (RP1095) with a modification on sample size. An aliquot of the sample solution is being used for the determination of calcium. Standard samples are being run regularly with these samples. The results are accurate to 2 1/2 percent of the total aluminum content of the rock.

It is probable that our fluorimetric method for the determination of aluminum in phosphate rock can be adapted to high aluminum samples. This will require redesign work on our fluorimeter. Work along these lines may be undertaken at a later date.

Bibliographic work, by F. Cuttitta

The annotated bibliographies on: 1. - Rare earths, 2. - Niobium and tantalum, 3. - Zirconium and hafnium, and 4. - Thorium, have been completed and all four are being combined for publication as a U. S. Geological Survey bulletin.

GEOCHEMICAL AND PETROLOGICAL RESEARCH ON BASIC PRINCIPLES

Distribution of uranium in igneous complexes

by E. S. Larsen, Jr.

Gottfried, Larsen and Smith have worked in the laboratory preparing material of various kinds and measuring activity by α -counter. Hayfield joined the project in January and White joined in May. Both are preparing rock samples and separating the minerals. Edgington has made twenty rock and mineral analyses for us. Kinser has supervised the chemical work part time and Waring has made many Pb determinations.

Cuttitta has completed his work on the fluorimetric determination of uranium in zircon (see section under "Analytic service and research on methods"). The original difficulty in obtaining accurate results for uranium in materials containing macro amounts of Zr has been overcome by the use of a matrix of salts (NaKCO_3 , $\text{K}_2\text{S}_2\text{O}_7$, or Na carbonate-borate). This is added to the platinum lid containing the sample solution prior to the final fusion step. This addition of matrix material dissolves the ZrO_2 and also distributes the uranium throughout the final flux pad.

Cuttitta has also completed his work on a rapid and accurate method for the determination of micro amounts of Th in the presence of macro amounts of Zr. Essentially the method consists of the extraction of Th with mesityl oxide in the presence of a phosphate used as a retainer for Zr. In the presence of 50 mg Zr, the following recoveries were made for the range of 50-150 g Th $100\% \pm 2\%$. The final measurement of Th was made colorimetrically with "Thoron" (see section under "Analytic service and research on methods").

Age

We have nearly completed our work on developing and testing a method for determining the age of fresh igneous rocks from the ratio of Pb to the radioactivity (chiefly α -counts per mg. per hr.) in zircon and other accessory minerals and we believe that we can determine the age of most rocks as old or older than Cretaceous with a range in separate determinations of 10 percent or less. Zircon of Cretaceous age that is very low in activity yields poor results. The zircon should contain at least 20 ppm of Pb for a fair age determination. Most Tertiary zircons unless very high in activity yield too little Pb for a good determination. We have a few good age determinations from xenotime. Xenotime is very good for age determinations as it is high in activity. We have found xenotime in several muscovite-garnet granites in both California and Idaho, in a garnetiferous granodiorite from California, and in a non-garnetiferous granite from New Hampshire. Thorite is present in very small amounts in some zircon concentrates from California and Idaho.

Preliminary work indicates that a mixture of thorite and zircon and probably each mineral alone will yield a good age determination. We have not yet finished tests with allanite and monazite.

In table 6 are listed some of the age determinations made by us. Under column 2 are listed the individual determinations each one made on zircon from a different rock or sample. The rocks commonly ranged from granite to quartz diorite. We believe that the method is about ready for routine age determinations. Two men should be able to determine the age of two rocks a week.

Table 6.--Age determinations of selected igneous rocks

	Age (millions of years). Each determination on a different rock.	Average ages	Number of rocks
Southern California batholith zircon	97, 114, 115, 113, 83, 130, 122, 116	111	8
xenotime	105, 119	112	2
Cuyamaca, California, Stonewall granite	78	78 (poor, Called Carboniferous)	
Sierra Nevada, batholith	109, 101, 111, 106	107	4
Idaho batholith	91, 130, 104, 88, 103	103	5
zircon	100	100	1
thorite and zircon			
New Hampshire, White Mt. magma series	247, 247, 240, 255, 201 227, 225, 255	238	8
Oklahoma,			
zoned zircons, fresh	608, 610, 600	606	3
metamict zircons	600, 570, 670, 615, 670, 646, 655	632	7
Mt. Tambani, Nyasaland, Africa zircon (from Prof. Tilley)	515, 569, 543, 523, 590, 535	546	6
Ceylon, zircon	555, 527, 619, 550, 591, 602, 560, 573, 607, 590, 570, 588, 604, 600, 561, 603, 643, 580, 644, 626, 586	590	21

Distribution of radioactivity in minerals of rocks

Table 7 shows the distribution of uranium in the minerals of two rocks from Southern California.

The amount of U and Th in zircons is highly variable and zoning is very strong. In the zircons from Ceylon each crystal is nearly constant but some crystals contain only 100 α /mg/hr--and others may be as high as 2200. The fresh cores of the Oklahoma zircons give from 150 to 326 α /mg/hr. and the metamict parts give 1050 to 1380. The early crystals to form--the cores of zoned crystals and the zircon in quartz diorites--seem to be low in radioactivity indicating that radioactivity concentrates in a marked degree in the residual liquid.

We have found the amount of zircon in the lavas of the San Juan Mountains of Colorado to be very low and the zircon to be very low in radioactivity. The zircons from the White Mountains magma series of New Hampshire are very high in uranium (as high as 0.5 percent) and that zircon is unusually high in radioactivity.

Table 7

The distribution of uranium in ppm in minerals of two rocks from Southern California

	Granite	Quartz diorite
Quartz and perthite	1.1	.6
Plagioclase	6.	2.2
Biotite, hornblende, pyroxene	9.	3.0
Magnetite	10.	7.
Allanite	35.	
Zircon	8600.	1040
Monazite		
Sphene		350
Apatite		37
Epidote		15.
Rock	3.2	1.8
U soluble in acid	60%	

Distribution of radioactivity in rocks of a petrographic province

The distribution of the uranium and thorium in the rocks of the Southern California batholith is shown in figure 25.

Distribution of radioactivity in petrographic provinces

To compare the uranium content of the rocks of two petrographic provinces it is necessary to compare rocks of similar character. Comparison of two very different provinces--the Southern California and the White Mountains rocks of New Hampshire--indicates that the White Mountain rocks are nearly twice as strongly radioactive as are the similar rocks of Southern California.

Weathering, transportation, and redeposition of uranium by R. M. Garrels

Although this project will not begin officially until the beginning of fiscal 1954, a considerable amount of preliminary work has been done. Garrels attended the Survey-AEC meetings on the Colorado Plateau project in February and also visited the Argonne Laboratories, where he discussed the proposed project with Drs. Katz, Hoekstra and Hinman.

Original emphasis on this project will be directed toward weathering processes in the Colorado Plateau area. As background for this, thermodynamic relations among the low-valence vanadium oxides that constitute a major part of some of the black "primary" ores of the Plateau have been assembled and a paper essentially completed on some thermodynamic relations among the vanadium oxides and their implications concerning the Colorado Plateau uranium-vanadium deposits. The major conclusion reached on this

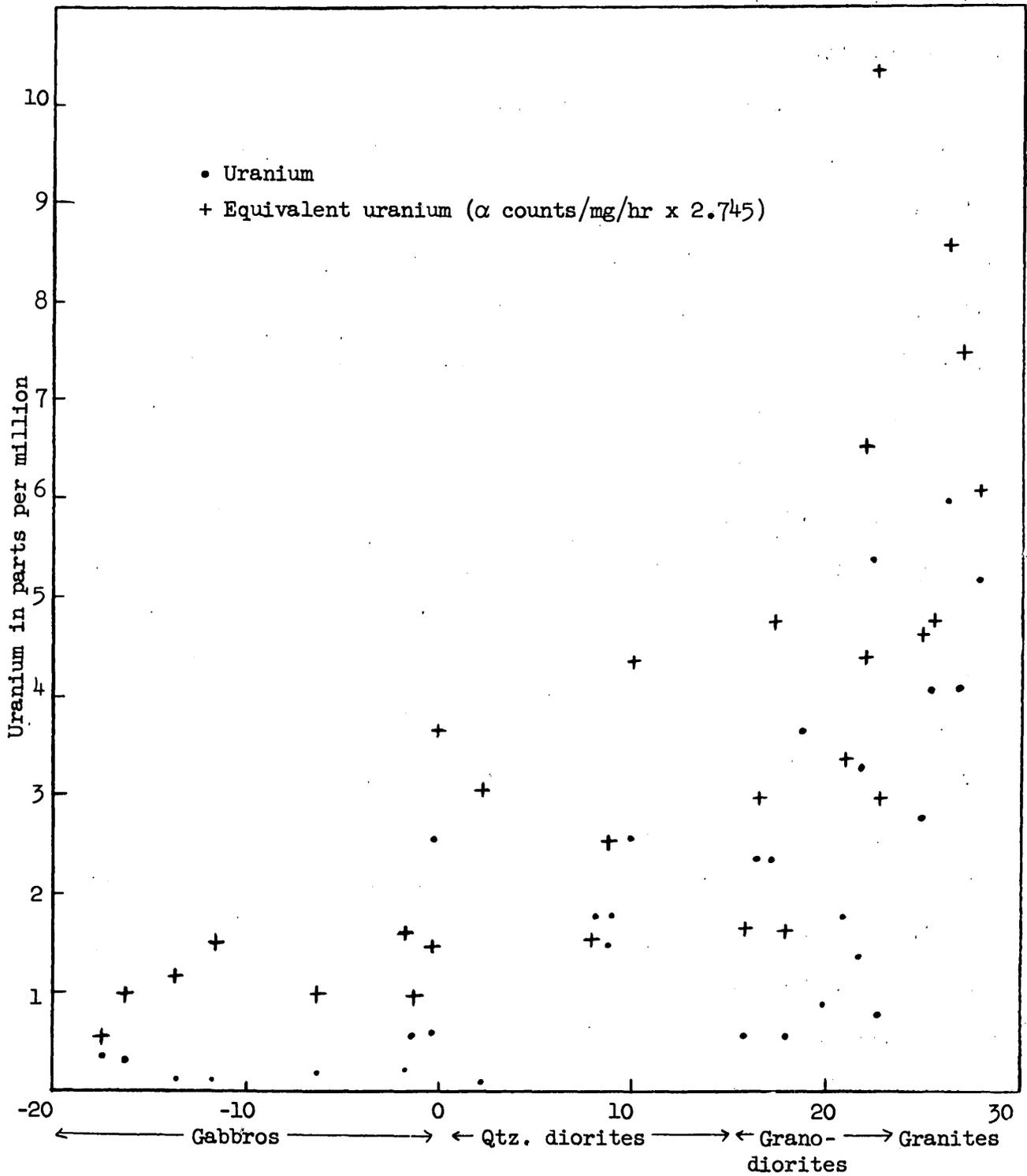


Figure 25.-- Position of rocks $1/3 \text{ SiO}_2 + \text{K}_2\text{O} - \text{FeO} - \text{MgO} - \text{CaO}$

DISTRIBUTION OF URANIUM IN ROCKS OF THE SOUTHERN CALIFORNIA BATHOLITH

work is that the low-valence vanadium oxides, pitchblende, galena, sphalerite, bornite, and other sulfides found associated in the "primary" ores are a thermodynamically stable mineral association under reducing conditions. Also, the tentative conclusion has been reached that carnotite, tyuyamunite, other 5-valent vanadium compounds, and 6-valent uranium compounds are a thermodynamically stable association under oxidizing conditions. Implication is, therefore, strong that the so-called "carnotite ores" are developed by oxidation under weathering conditions of an earlier mineral suite stable under reducing conditions.

This implication will be investigated in the field and in the laboratory. Field work will consist of detailed mapping and sampling of a developing mine, chosen to illustrate both "primary" and "oxidized" ore. In the laboratory recording equipment for the continuous measurement of pH and oxidation potential for six simultaneous experiments has been ordered and should be received before July. The theoretical and field relations will be investigated with this apparatus.

A partial survey of the literature necessary to develop thermodynamic field stability of the various uranium minerals has begun; search will be continued; it may be necessary to obtain some basic free-energy data in the laboratory.

A part of the proposed staff is already available but the most pressing need, in terms of additional personnel, is for a research chemist with major interest in the field of chemistry of ionic solutions.

Supporting work from Geological Survey funds is being performed by Miss Margaret D. Foster, who is studying the geochemistry of the vanadiferous clays. Her first work has been on the characterization of

these little-understood clay-like minerals. She proposes to continue this aspect and also to investigate the fixation of vanadium by various clay minerals. This is one of the major geochemical problems in any theory that explains the development of the "carnotite type" ores as a result of oxidation of a primary assemblage of low valence vanadium oxides.

Synthesis of uranium-bearing minerals
by Irving Friedman

The investigation of the system $K_2O-V_2O_5-H_2O$ is nearing completion and work on the $K_2O-V_2O_5-H_2O-UO_3$ system will begin shortly. The stability fields of 12 solid potassium vanadates have been delineated and their composition determined by analysis. Phase diagrams are included with this report. (Figures 26-31.)

The system $Na_2O-ZrO_2-H_2O-SiO_2$ is being investigated at temperatures above $400^\circ C$. Instrumental difficulties, now overcome, have prevented our obtaining the information we had hoped to obtain. Runs are now in progress at temperatures $500^\circ C$ and pressures of about 10,000 p.s.i.

More work was done on the rare-earth fluo-carbonates. Varying amounts of HF were added to cerium and calcium salts stoichiometrically mixed and the products were kept in a CO_2 atmosphere at $30^\circ C$. X-Ray and optical tests showed all products to be fluocerite.

To provide material for electron photomicrographic measurements of fritzschite, this mineral was synthesized again by methods described in a previous report.

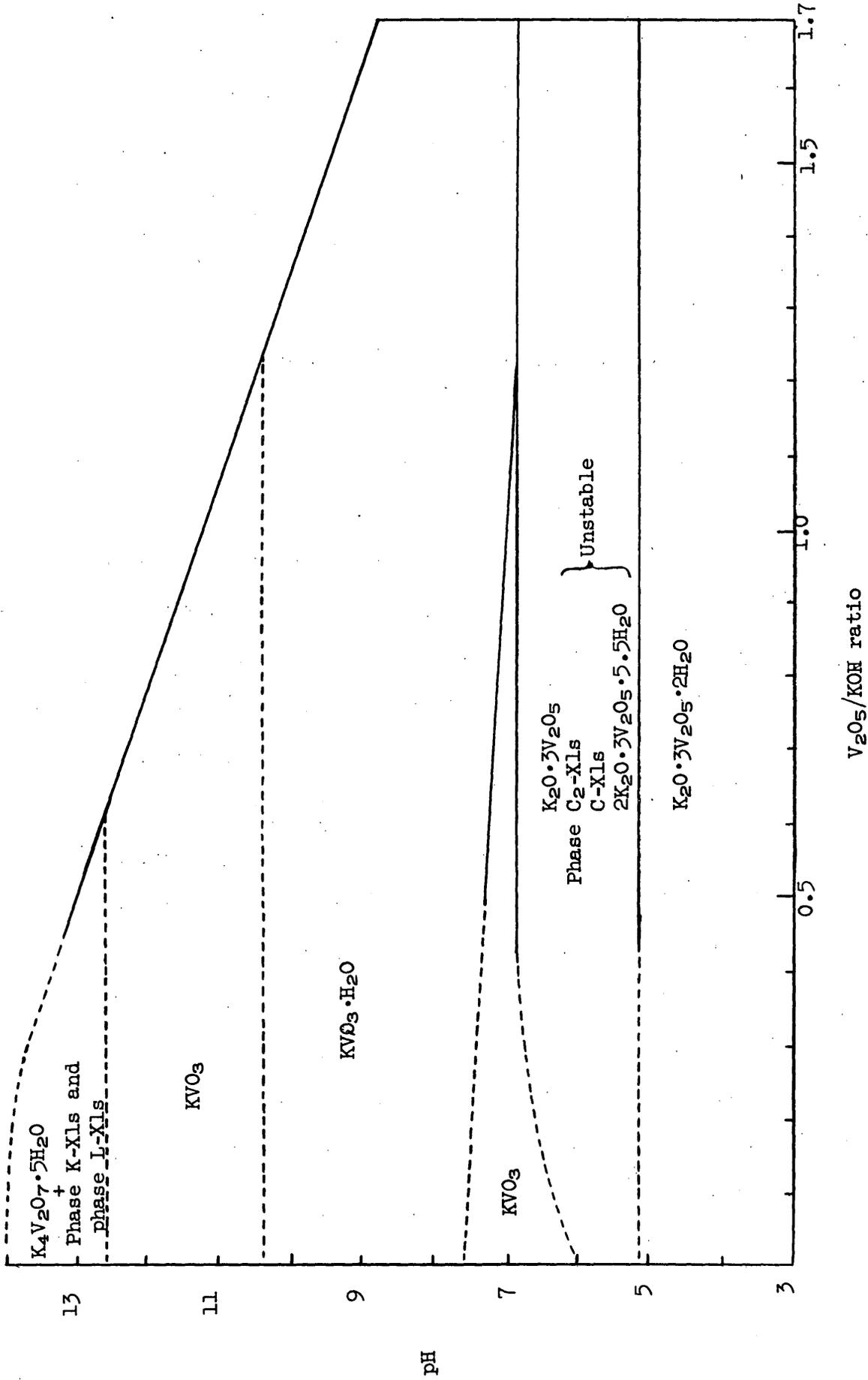


Figure 26.---Phase boundaries at 17°C

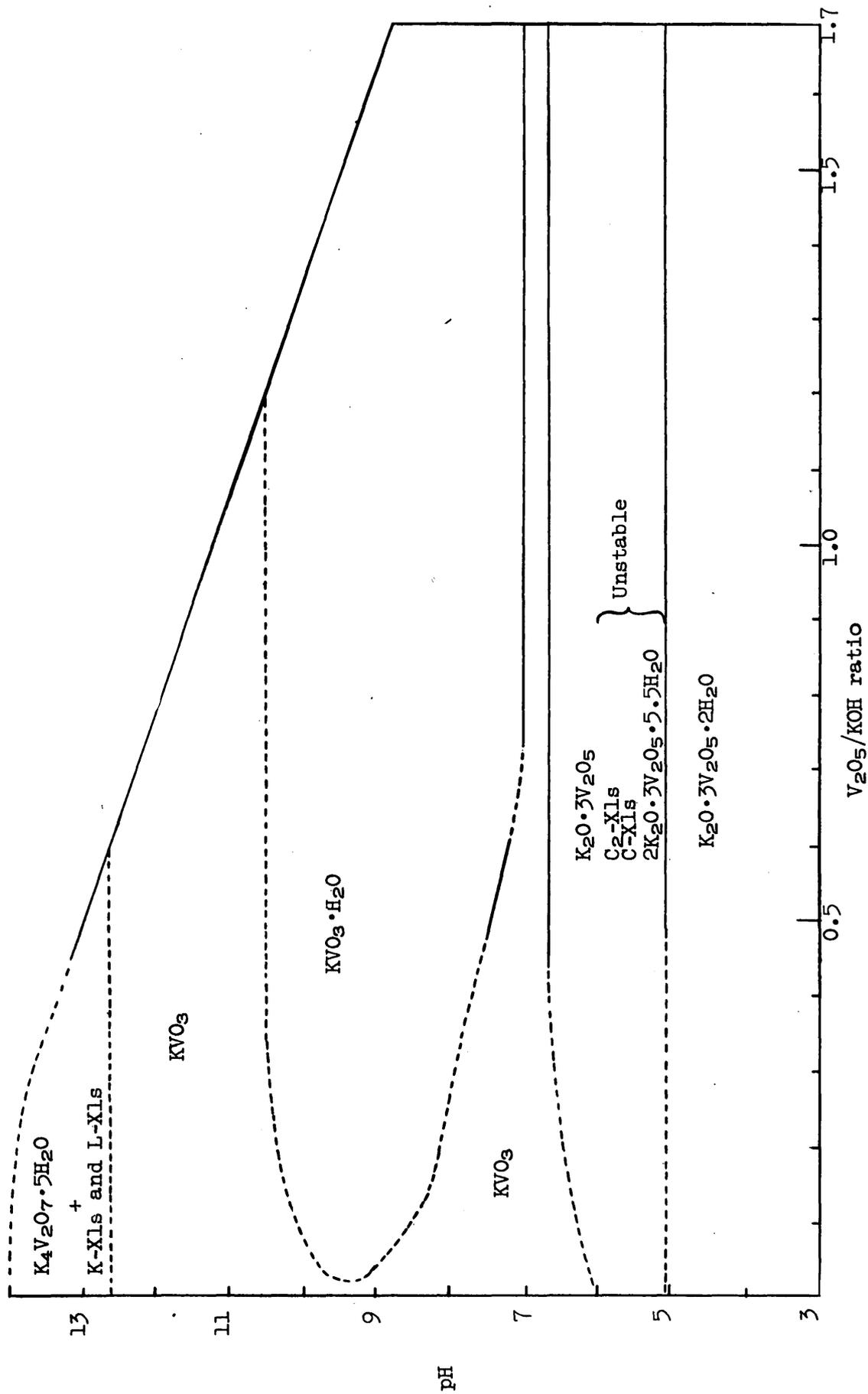
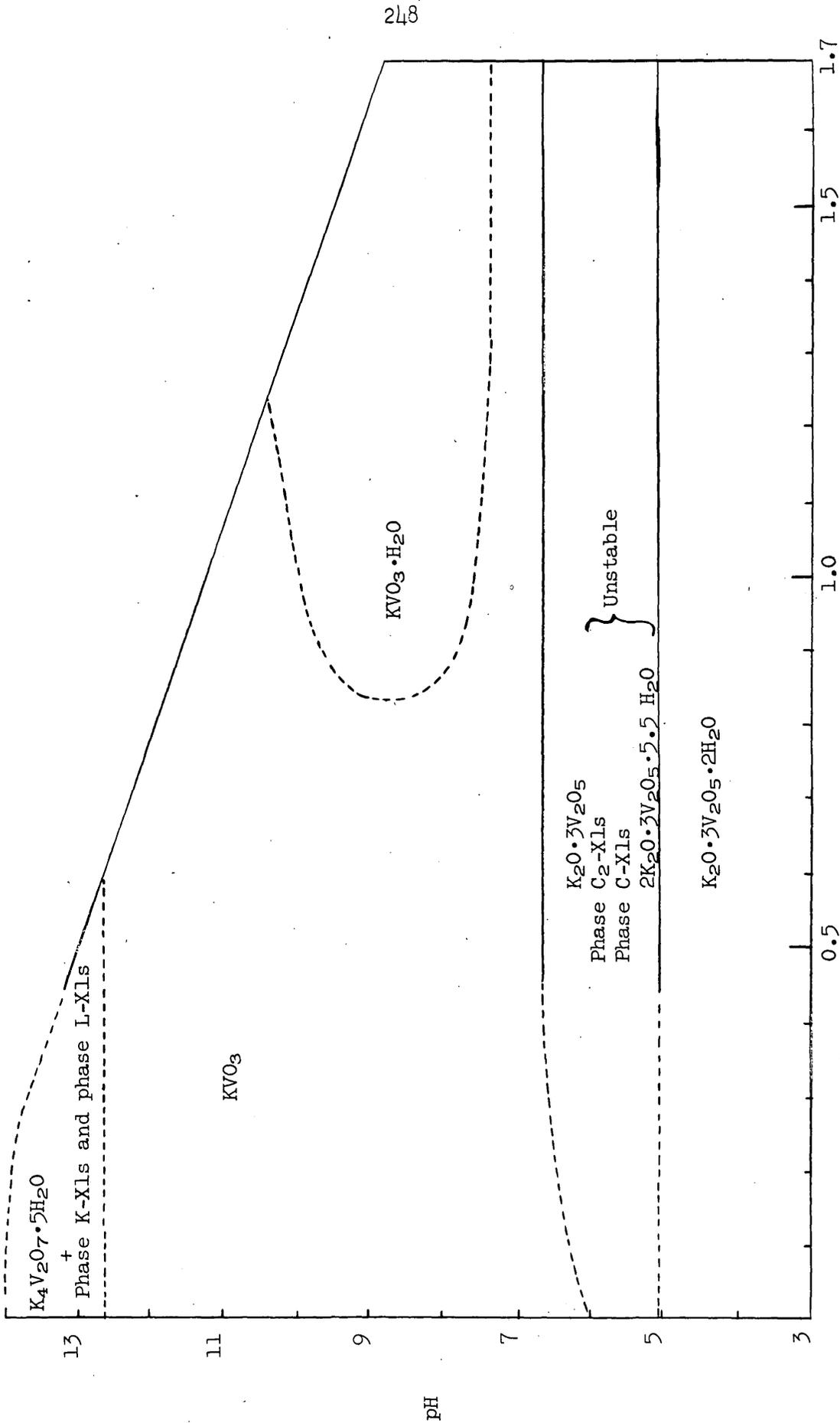


Figure 27.-- Phase boundaries at 25°C



248

Figure 28. --- V₂O₅/KOH ratio

Phase boundaries at 30°C

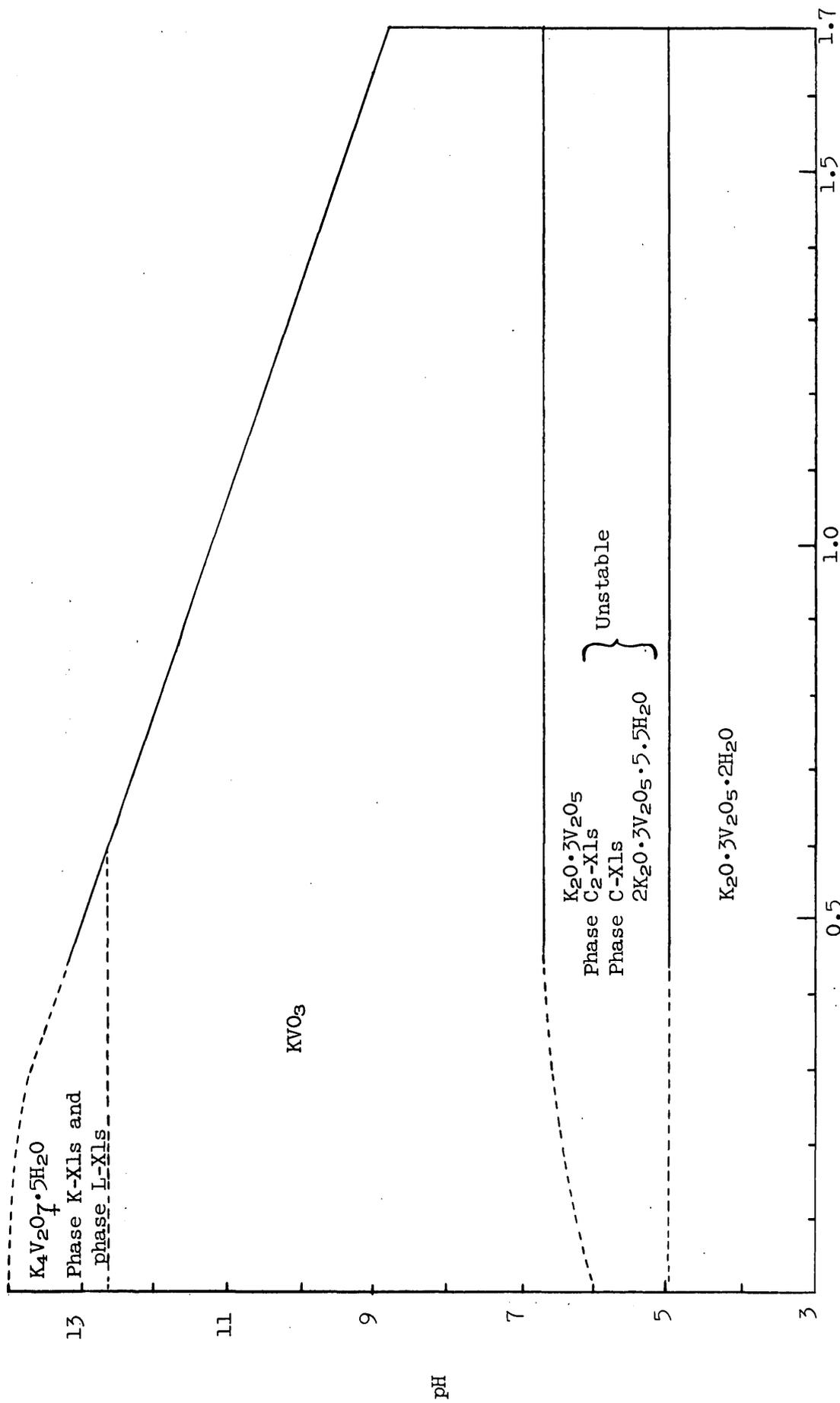


Figure 29. --- V_2O_5 / KOH ratio

Phase boundaries at 35°C

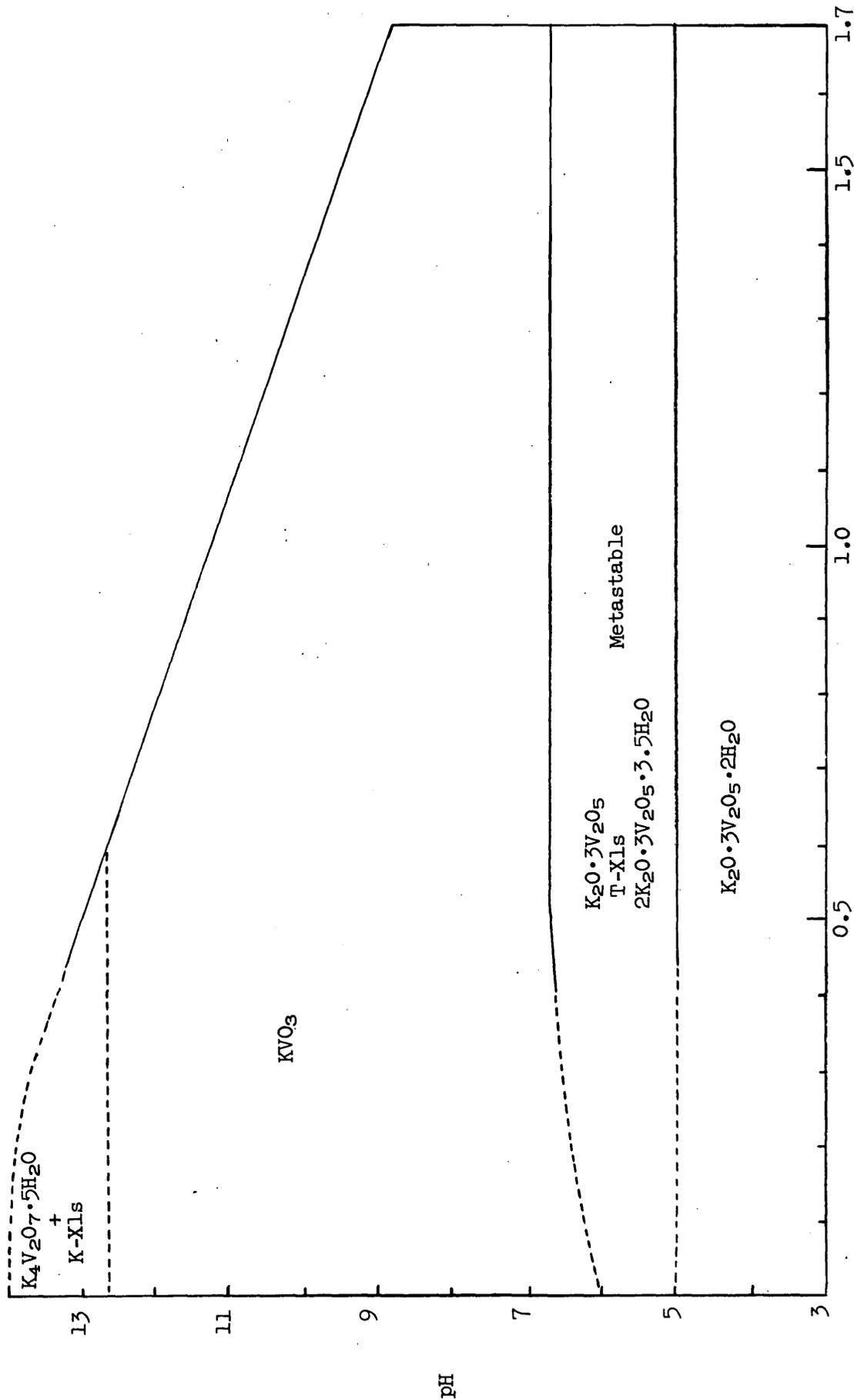


Figure 30.---V₂O₅/KOH ratio

Phase boundaries between 40° and 60°C

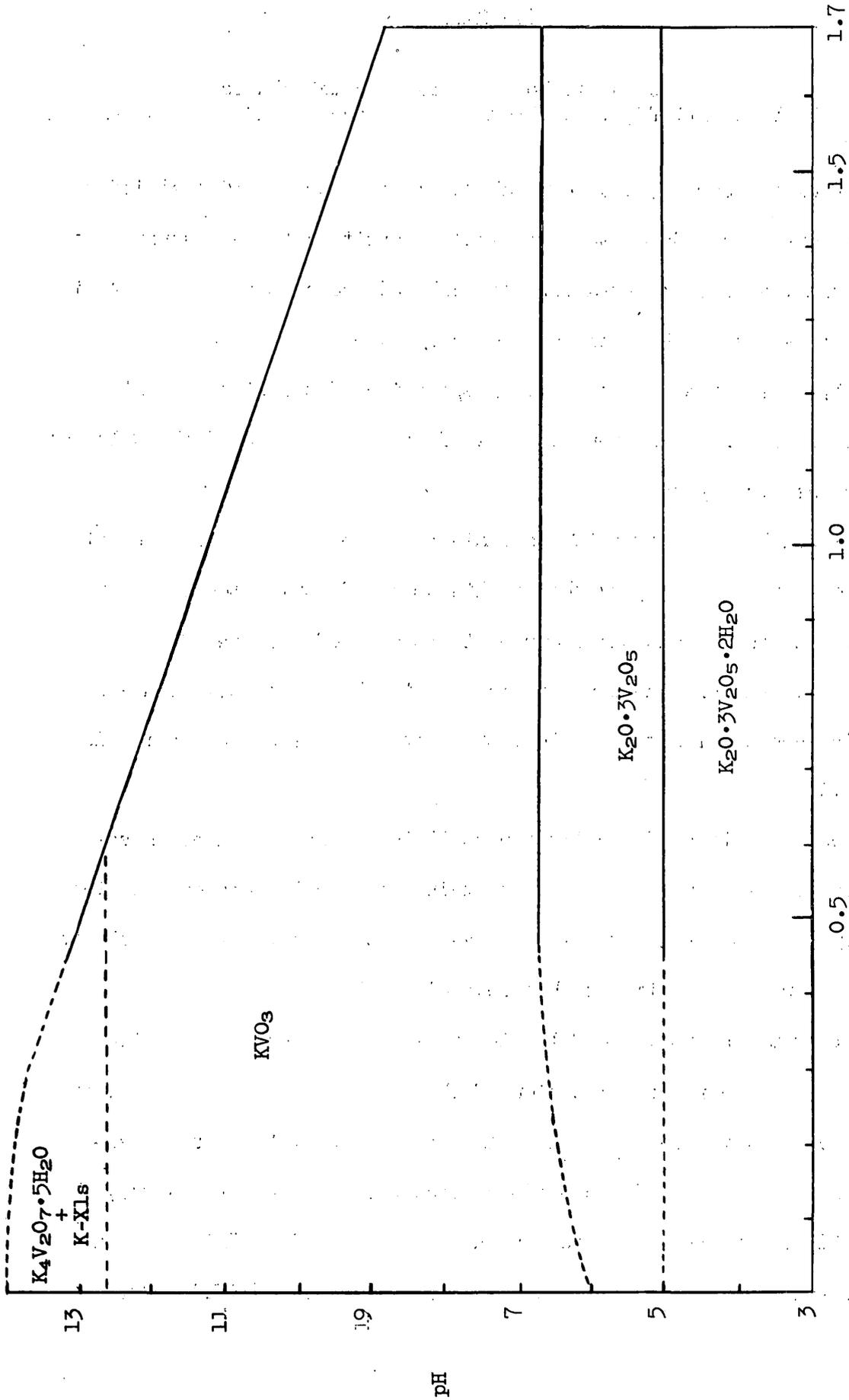


Figure 31.-- V_2O_5/KOH ratio

Phase boundaries between 60° and 90°C

Isotope geology

Isotope geology of the Colorado Plateau
by L. R. Stieff, T. W. Stern, R. A. Powell, and H. Mela, Jr.

During the period, 173 chemical determinations and 40 lead iodide preparations were made on some 76 samples submitted for age studies and 21 new samples were prepared for chemical and isotopic analysis. Additional analytical work is planned for only a very small number of carefully selected specimens. The preparation of the final reports summarizing several different aspects of the age studies of the Colorado Plateau has already begun.

The conclusions given in the semi-annual report TEI-310 have not been modified in any way by the results obtained during the last six months. At the present time, our best estimate of the age of the Colorado Plateau uranium deposits in both the Morrison formation and the Shinarump conglomerate is that these ores are less than 65 million years old.

Upon completion of the light-mass 6"-60° permanent magnet mass-spectrometer, work was resumed on certain electrical components of the 6" heavy mass-spectrometer. The heavy-mass mass-spectrometer should be completed and in operation within several months.

During the period, the following three reports were transmitted to AEC: "A preliminary determination of the age of some Colorado Plateau uranium ores by the lead-uranium methods" (TEI-268), "An air concentrator for very low grade Colorado Plateau uranium ores" (TEI-307), "The lead-uranium ages of some uraninite specimens from Triassic and Jurassic sedimentary rocks of the Colorado Plateau" (TEI-322).

The work described in TEI-307 was begun in 1950 as part of the lead isotope studies of very low grade Colorado Plateau uranium ores. A preliminary concentration of these low grade ores was desirable because of the serious problems in chemical extraction of the lead for isotope analysis and in the quantitative analysis of these samples for both lead and uranium. It was soon found, however, that the very low grade ores were generally unsuitable for age determinations because in many of them the uranium had apparently been selectively leached by surface and ground waters. In spite of the limited use of this concentrator in the geologic age problem of the Colorado Plateau, the report was prepared to indicate the possible applications of a modification of this concentrator for problem of enrichment of low grade Plateau ores prior to the shipment of the ores from the mine and to other problems in separating extremely fine grain particles from poorly sorted sediments. If the average low grade sandstones of the Plateau are similar to the two low-grade sandstones studied, a minimum of a 10-fold enrichment in uranium in the concentrates can be expected.

Diffusion studies
by J. T. Bracken and F. E. Senftle

A theoretical study has been made of diffusion as a process of isotopic fractionation in nature. It is shown that a few percent fractionation can be expected in a crystal by diffusion processes, but only if a nearly-total replacement of a given element has taken place. Fractionation across a boundary has also been considered, and the results are similar to those obtained for a crystal. These studies have indicated certain precautions which should be taken in sampling for mass-spectrometric analysis.

Instrumentation

by I. Friedman, L. R. Stieff, M. D. Lee, H. Allen and A. R. Nelson

The light-mass machine has been placed in operation, and minor adjustments, alignment, and tuning has taken several months. It is now ready to run hydrogen-deuterium ratios and another source is under construction to convert this machine for use with carbon dioxide.

The partial redesign and building of the heavy-mass mass-spectrometer has been greatly impeded by the resignation of Harold Allen, our electronic technician, and the death of R. A. Nelson. However, we hope to complete this revision in a few months.

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

Work contributing to the study of variations in the isotopic composition of lead in diverse geologic environments throughout geologic time has been continued on many fronts. The most significant change in orientation of work being done under the project is a new research problem in the cooperative program with the geochemists at California Institute of Technology. In 1952 a study of the readily dissolved constituents of crystalline rocks was started by the CIT group as an activity in the interim prior to completion of the mass spectrometers. These soluble constituents comprise a small but intriguing portion of rock material that can be dissolved in just a few minutes by nitric acid (IM) percolating through crushed granitic rock at room temperature. This fraction may be enriched in several rock-forming elements like calcium and aluminum as well as in some accessory elements like uranium and lead.

Commonly about one-third of the alpha activity is readily dissolved from a plutonic rock in this fashion. The geologic distribution and significance of this material is the objective of intensive study in the CIT laboratory, and work has been done on 8 rocks to date. As a Survey contribution to this study, a number of Survey geologists have been contributing recommendations, geologic data, and sample materials that are needed for formulating the geologic orientation of the research. Ralph Cannon and George Neuerburg have served as coordinators of these contributions, and Neuerburg has also been actively participating in the petrographic aspects of the work in the CIT lab. Dr. Harrison Brown of CIT directs this research and will report its findings.

One important contribution to progress on isotope geology of Pb is hoped to result from these "leaching studies". An understanding of the geologic nature of that portion of Pb, U, and Th that can be easily dissolved from igneous rocks is needed to interpret correctly the balance of Pb-, U-, and Th-isotopes in plutonic rock systems, either for geologic dating or for interpreting their geochemical history. In the CIT lab additional progress on the isotope geology of Pb is being made along other lines. Claire Patterson is continuing in cooperation with George Tilton (now of Carnegie Institution) work they had started in an earlier year at Chicago on the Pb-, U-, Th-isotope regimen of 2 granites; he is also continuing work on isotopic composition of Pb in meteorites and the oceans. In recent months Patterson has selected an initial group of samples (mostly basalts and limestones) from among the large number we have collected for cooperative studies on Pb-isotope geology and is extracting the traces of rock-Pb from the samples for isotope analysis. Cannon visited the CIT lab for a month in February and March to promote coordination on work of mutual interest.

Lead-isotope investigations have been continued by Cannon and others through the facilities of the Survey's Washington laboratories and the Mass Assay Lab at Oak Ridge, working especially with Pb-rich materials. During the period a manuscript was mostly written on variations of isotopic composition of Pb in a galena crystal from the Tri-State district, Okla.; 17 samples were prepared for isotope analysis (10 primitive galenas, and 7 concentric layers of a marine manganese nodule); and 17 isotope analyses were completed on earlier samples of galena-Pb. Samples of galena-Pb analysed to date have been selected especially to yield the kind of information on the nature and magnitude of isotopic variations in Pb ores that is needed at the outset in order to establish valid sampling techniques and to permit intelligent interpretation of isotope data. We have now obtained an appreciable fund of such information which is summarized in table 7 for the guidance of others who are concerned with sampling mineral deposits for Pb-isotope analysis. Most published articles dealing with Pb-isotope variations seem to imply the tacit assumptions that isotopic differences between samples of Pb from different localities and of different ages may be small or great, but that Pb at any one locality (district, ore body, hand specimen) is substantially uniform in isotopic composition. The latter clearly is not a justified assumption, and table 8 gives the magnitude of departures from such uniformity. The first line (A) of the table gives an example of the reproducibility of these mass spectrometric analyses; the last line (J) summarizes the extreme variations that have been found among all 30 samples of varied provenience that have been analyzed for this purpose. In general this range of extreme variations seems to be on the order of

Table 8.—Variations between measured Pb-isotope ratios of galena samples (maximum range in variation of ratio, expressed as percent)

		$\frac{\text{Pb}^{206}}{\text{Pb}^{204}}$	$\frac{\text{Pb}^{207}}{\text{Pb}^{204}}$	$\frac{\text{Pb}^{208}}{\text{Pb}^{204}}$
Group I.	Duplicate analyses.	A. 0.44%	0.09%	0.04%
Group II.	Variations correlated with only minor or small-scale differences in environment of sample.	B. .09	.01	.13
		C. .27	.51	1.16
		D.1 .15	.39	1.03
		D.2 1.49	1.67	2.31
		E. 1.00	.54	.49
		F. 4.38	1.36	3.01
Group III.	Variations correlated with major differences in environment of samples.	G.1 .22	.11	.11
		G.2 1.61	1.81	3.63
		H.1 .82	.47	.81
		H.2 1.36	.47	1.06
		H.3 4.61	2.02	3.89
		I. 7.94	2.31	2.03
J. 48.18	8.88	21.69		
Group I.	A. Two analyses of identical sample of Pb-iodide (Tri-State, Okla.): An example of the reproducibility of these analyses.			
Group II.	B. Analyses of 2 samples from same growth layer of a galena crystal (Tri-State, Okla.): One sample from a cube-face position, the other from an octahedral-face position.			
	C. Two samples of galena concentrated from the same hand specimen (Magnet Cove, Ark.): One handpicked concentrate, the second an insoluble residue from treatment with dilute acetic acid.			
	D. Samples from Upper Silesia:			
	D.1 Two samples handpicked from different layers of a laminated Pb-Zn-sulfide ore.			
	D.2 A third sample (from a second specimen, same mine, from interior of a cube-octahedral crystal) compared with the 2 above samples.			
	E. Two samples from 2 hand specimens from same ore body (Pecos mine, N.M.).			
F. Seven analyses of 6 samples from 5 different growth layers of a cubic crystal of galena (Tri-State district, Okla.).				
Group III.	G. Samples from the crystalline rocks of the Appalachian region:			
	G.1 Two samples from 2 mines in the Piedmont Province, 200 miles apart.			
	G.2 Third sample from a mine in the Blue Ridge Province compared with the 2 samples above.			
	H. Samples from the Metaline district, Washington and British Columbia:			
H.1 Two composite samples of mill concentrate from 2 adjoining mines, replacement ore in the same horizon of Middle Cambrian limestone.				

- H.2 Third composite sample of mill concentrate from a 3rd mine, 12 miles north, replacement ore in an older limestone horizon, believed of Lower Cambrian age, compared with the 2 samples above.
- H.3 A 4th sample from a prospect 25 miles south, galena in hydrothermally altered and mineralized quartz monzonite in the interior of the Kaniksu batholith (possible source of Pb in the limestone replacement deposits) compared with the 3 samples above.
- I. Two samples from 2 mines only 4 miles apart in the same district (Lead, S.D.) but from dissimilar types of ore bodies that may have formed at different times by different geologic processes.
- J. Extreme variation among 30 samples of galena from miscellaneous environments.

problems, and similar consultation was carried on with other scientists by correspondence and in person at scientific meetings attended in April and May (Neuerburg: Rocky Mt. Section, Geol. Soc. Am.: Cannon: Nat. Acad. Sci., Am. Geophys. Union). Laboratory work on sample materials at the Gun Factory Laboratory included semiquantitative spectrographic analyses of 150 samples, about 50 quantitative spectrographic determinations of Pb, and 20 fluorimetric determinations of U. A suite of galena samples was prepared for sulfur-isotope analysis, and zircon and apatite concentrates were prepared from gabbro in the San Gabriel anorthosite for U and Pb-isotope investigation. Neuerburg undertook petrographic work on nearly 150 samples and completed studies on about 60. The data obtained on samples in our collections have been used in choosing a limited number for more intensive study in initial stages of the leaching and isotope programs. When these data are more nearly complete, their geochemical implications will be reviewed more systematically. Minor research has been done on other miscellaneous problems arising incidentally from project activities, including the following topics: Composition of twin lamellae

100-times or more greater than the analytical uncertainty. Group II shows the magnitude of variations at single localities, including the demonstration that variations even within a single specimen can amount to 10 percent or more of the extreme variations found among all 30 samples. The variations in this group are correlated with only minor differences in geologic environment or occurrence, where no factors are in evidence that might be expected a priori to cause substantial isotopic variations. Group III, however, shows variations correlated with major environmental differences that might be expected to be accompanied by isotopic variations. Unexpected results in the group are cases like G.1. where isotopic differences are practically nil despite notable environmental differences. These new data on galena-Pb need to be supplemented with the earlier findings of others: Nier's published articles include data on Pb from different mineral species from the same locality: Stieff and Stern of the Survey have found very large systematic variations in galena-Pb from the Colorado Plateau region; Collins, Farquhar, and Russel of the University of Toronto have found very large differences between samples of galena-Pb from the Sudbury district, Ontario. Taken together, these data now provide a guide that at least illustrates some of the pitfalls that need to be appreciated if sampling, isotope analysis, and interpretation of ore-Pb are to be established on a scientific basis.

To complete the record, other project activities during this period are briefly summarized. About 60 additional samples of rocks, minerals, and fossils for isotope or leaching studies were chosen and collected. A large number of Survey scientists were consulted on sampling

in plagioclase; origin of tachylite at Craters of the Moon, Idaho; petrology of pegmatite at Pacoima Canyon, Calif.; anisotropism in chromite; radioactivity vs. grain-size fractions of crushed granitic rocks; and radioactivity of stream alluvium downstream from uranium deposits.

X-ray crystallography
by H. T. Evans, Jr.

The work of R. Marvin and I. Friedman (Synthesis of uranium minerals project) on the system of $K_2O-V_2O_5-H_2O$ is being followed by crystallographic studies on the products on their study. In systems of pH lower than 6, several well crystallized orange phases have been examined. A typical complex has the composition $K_6V_{10}O_{28} \cdot 10H_2O$, is triclinic, strongly pseudo-monoclinic; with 4 molecules in the monoclinic unit. Other phases which appear simultaneously at room temperature are apparently different hydrates of the same complex. Other phases that have been identified are $K_2V_6O_{16}$, which is monoclinic, space group $P2_1/m$ or $P2_1$, $a = 7.68\text{\AA}$, $b = 8.43$, $c = 5.00$, $\beta = 96^\circ 45'$, with one formula per cell; and $K_3V_6O_{16}$ (provisional) which is trigonal, space group $P3/m$, $a = 8.78\text{\AA}$, $c = 5.00$, with one formula per cell.

The decavanadate complexes are apparently completely analogous to the mineral hummerite, $K_2Mg_2V_{10}O_{28} \cdot 16H_2O$. The crystallography of artificial material has been determined (confirming E. Cisney's previous rough measurements) as follows: Space group $P\bar{1}$ (triclinic), $a = 10.81\text{\AA}$, $b = 11.01$, $c = 8.85$, with one formula per cell. It was decided to ascertain the structure of the decavanadate complex from an analysis of this crystal. To that end, intensities have been measured for the planes $(hk0)$, $(0kl)$ and $(h0l)$, and the three corresponding Patterson projections have been prepared.

The $K_2O-V_2O_5-H_2O$ system at pH above 6 is colorless and produces two prominent phases, KVO_3 (orthorhombic) and $KVO_3 \cdot H_2O$ (orthorhombic). A complete structure analysis has been carried out on the latter. The results are tabulated below:

Potassium metavanadate, $KVO_3 \cdot H_2O$
 Space group: $Pnam$ (D_{2h}^{16}), orthorhombic.
 Cell constants: $a = 8.223 \text{ \AA}$, $b = 13.54$, $c = 3.698$, $Z = 4$
 Atomic coordinates: 4V, 4K, 4OI, 4OII, 4OIII, 4OIV,
 (H_2O), all in (c): $(x, y, 1/4)$; $(x, \bar{y}, 3/4)$; $(1/2 = x,$
 $1/2 + y, 3/4)$; $(1/2 + y, 1/2 - y, 1/4)$.

	V	K	OI	OII	OIII	OIV
x	.073	.245	.494	.272	.058	.120
y	.081	.279	.306	.098	.042	.413

expressed in fractions of unit cell edge.

The water molecule, whose presence was not suspected at the outset, appeared unmistakably in the electron density mappings. (Thus, this phase has been previously referred to as β - KVO_3). The structure is now being refined by three-dimensional methods. This structure has proved to be exceeding interest because it contains a chain linkage which appears to be very commonly assumed by pentavalent vanadium oxy-compounds. In the chain, the vanadium atom is in strict five-fold coordination with oxygen atoms, and the chain is formed of the trigonal dipyramidal polyhedra by shaving edges in a zig-zag manner. The same chain had been previously found, in highly distorted form, in the oxide V_2O_5 . Barnes and Qurashi of the National Research Council of Canada have very recently demonstrated its existence in hewettite. We have found it in two new minerals from the Colorado Plateau (under study by A. D. Weeks and M. E. Thompson). (1) A red brown fibrous mineral approximately $V_2O_5 \cdot 3H_2O$; and (2) a dark green fibrous mineral which reacts violently in acid to produce red fibres, and because of its close

association with calcite may be a carbonate complex. No single crystals of these minerals have been found, but they all give rotation patterns which show the short 3.7\AA fibre spacing which is characteristic of the chains described above. Apparently, the chain motive is a prominent one in a certain class of vanadate minerals.

Stanley Block has rejoined our staff for the summer, and has commenced work on KVO_3 (previously designated as $\beta\text{-KVO}_3$). At this time a Patterson electron density map has just been completed.

Uranium mineral structures

A program of study has been started on the crystal structures of uranium minerals in three phases: (1) the carnotite problem; (2) uranium oxides and hydrates; and (3) miscellaneous uranium minerals.

Dr. Gabrielle Donnay, (WAE) at Johns Hopkins University, has taken up the carnotite problem. She has under study crystallized specimens of carnotite, tyuyamunite, sengierite and the closely related phosphate complexes autunite, torbernite, zeunerite, etc. All of these layer structures show more or less disorder, and it now appears that the crystals are better, the smaller the interlayer cation, and the higher its charge, in a manner analogous to the silicate micas. It is planned to carry out detailed structure analysis on sengierite, $\text{Cu}(\text{UO}_2)_2(\text{VO}_4)_2 \cdot 8-10\text{H}_2\text{O}$, which shows the best crystals.

In connection with the second phase, uranium oxides and hydrates material has been gathered for studies on curite, schoepite and fourmarierite. Preliminary literature study and discussions with Dr. H. Hoekstra at the Argonne National Laboratories in Chicago have

indicated the needs for crystallographic studies on artificial and natural pitchblende and uraninite. It is planned to carry out such studies in conjunction with the synthetic minerals program.

Parisite problem

Dr. Donnay has continued structure studies of the parisite group minerals and cordylite, in order to establish firmly the crystallographic work previously reported. The final manuscript on this problem has been prepared and is under revision. A short note on the new species roentgenite in the parisite series is being cleared for the American Mineralogist.

Publications

Four titles and abstracts have been submitted for the program of the meeting of the American Crystallographic Association scheduled for June 22-26 at Ann Arbor, Michigan, as follows:

"The crystal structure of montroseite, a new vanadium analog of diaspore," by H. T. Evans, Jr. and Stanley Block

"The crystal structure of $KVO_3 \cdot H_2O$," by C. L. Christ, J. R. Clark and H. T. Evans, Jr.

"The crystal chemistry of vanadium compounds and minerals," by H. T. Evans, Jr.

"The 'polycrystal', a product of syntaxial intergrowth," by Gabrielle Donnay

Other papers in various stages of editing are as follows:

"Use of a Geiger counter for measurement of intensities from small single crystals," by H. T. Evans, Jr., appeared in March issue of Review of Scientific Instruments

"The crystal structure of $KVO_3 \cdot H_2O$," by C. L. Christ, J. R. Clark and H. T. Evans, Jr., note to appear in June issue of Journal of Chemical Physics

"Roentgenite, $3CeFeCO_3 \cdot 2CaCO_3$, a new mineral from Greenland," by Gabrielle Donnay, a note for American Mineralogist being edited by USGS

"A crystallographic study of the bastnaesite-parisite-roentgenite-synchisite group of minerals," by Gabrielle Donnay, under revision, to be published in the American Mineralogist

"The crystal structure of montroseite, a new vanadium analog of diaspore," by H. T. Evans, Jr. and Stanley Block, being edited for a TE report

"The crystal geometry of some alkali silicates," by Gabrielle Donnay and G. H. Donnay, appeared in American Mineralogist, Vol. 38, pp. 163-171, 1953

Radon and helium studies

by G. B. Gott, G. E. Manger, H. Faul

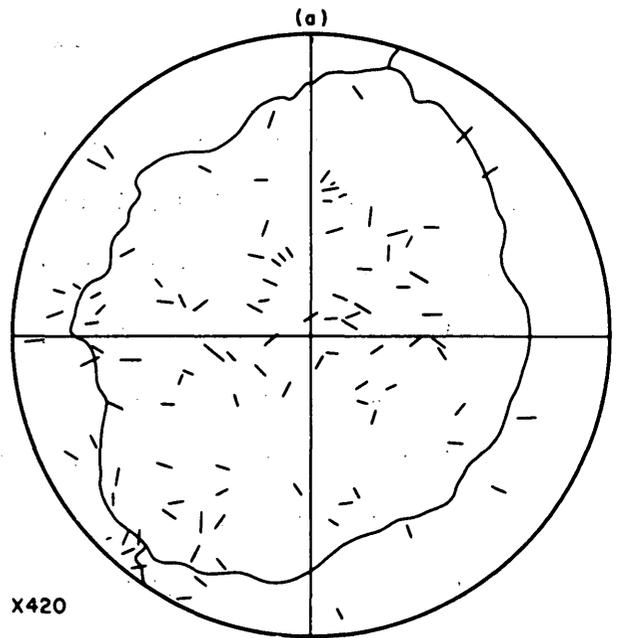
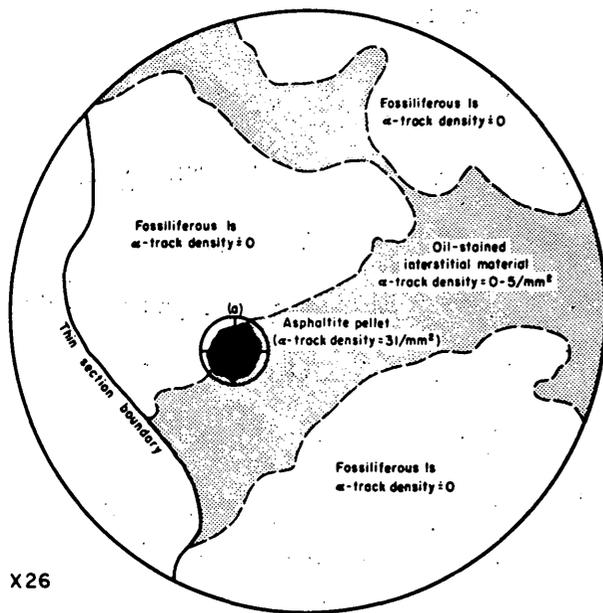
The objectives of this investigation are to determine the distribution and origin of the radon, helium and the parent radioactive elements in the western part of the Panhandle gas field in Moore and Potter Counties, Texas, and in the immediately adjoining Hugoton gas field to the north. The investigation during the period covered by this report included principally: (1) a study of the distribution of uraniferous asphalts, with quantitative and qualitative analyses of the material, (2) analyses of 6 core samples to determine the distribution of uranium, radium and radon among the dolomite rock matrix and the interstitial water, residual oil and natural gas in the pore space, and (3) study of the transient gas flow problem.

Uraniferous asphalts

Several porous limestones and dolomitic limestones that contain significant amounts of uraniferous asphalts have been found. The gross uranium content of these rocks ranges from 0.003 to 0.006 percent and preliminary data indicate that the asphalt itself contains 0.3 percent U or more. Alpha tracks on nuclear emulsions (fig. 32), show that the radioactivity of these rocks is concentrated in the asphaltic material, which is restricted to the pore space and constitutes 1 or 2 percent of the rock volume. Uraniferous asphalt is found in the areas of highest radon concentration.

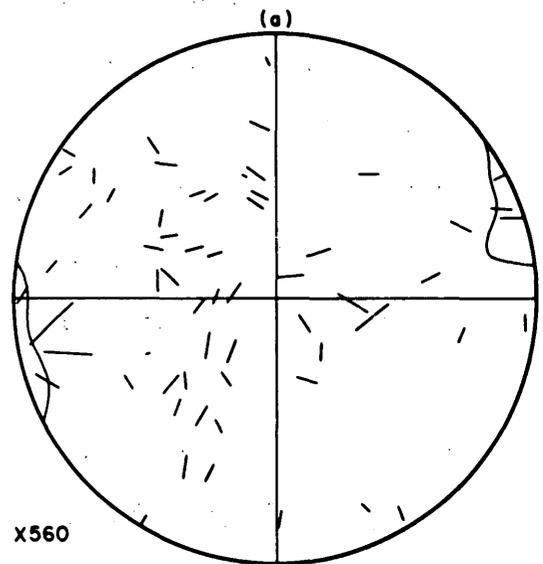
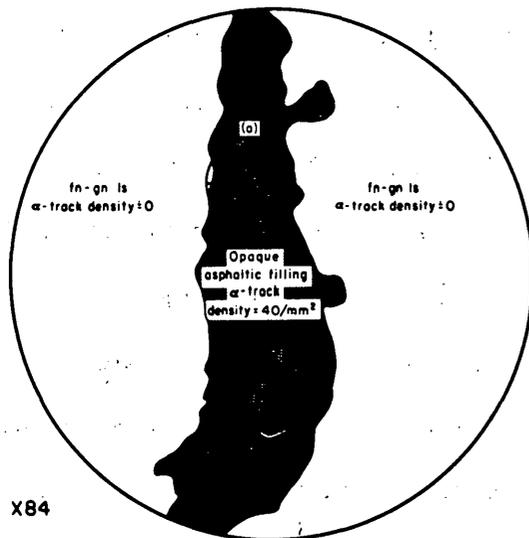
Analyses of core samples

The analyses of the core samples to determine the distribution of the uranium, radium and radon between the rock matrix and the fluid contents in the pore space consist of chemical, physical and radioactivity tests made over a period of more than a year. These core samples from a well in Moore County, Texas, are the only cores obtainable in this area from a well producing natural gas with an appreciable radon content. The samples are cable-tool cores of typical Brown dolomite from the gas-producing zone, although they certainly represent less permeable and porous portions of the formation. The analyses have been made by the U. S. Bureau of Mines, the Oak Ridge National Laboratory and the U. S. Geological Survey Washington Trace Elements Laboratory. Data has been supplied making it possible to derive relationships among the average values of porosity, permeability, and interstitial water saturation.



X26

X420



X84

X560

Fig. 32

The numbered items of the accompanying table 9 present some of the more important analytical data of six samples and some significant derivations calculated therefrom. Some conclusions indicated by these items are:

1) Total uranium in the entire rock (Item 1) ranges from 0.000002 to 0.000051 g^U/g, and the uranium/radium ratio (Item 9) ranges from 0.75 equilibrium to 9.4 times equilibrium.

2) Water-soluble uranium - uranium soluble in distilled water at 30° C in the laboratory - is about 0.001 to 0.0001 (Item 2) of the uranium in the whole rock.

3) Uranium recovered from the residual oil - a slight saturation of non-productible oil - as a part of the total rock (Item 4) is only about 0.01 or less of the water-soluble uranium in the total rock (Item 3).

4) Concentration of uranium in the residual oil (Item 5) is no more, and may be less, than the calculated concentration (Item 6) of uranium in the interstitial water (in the porosity). Concentration of uranium in the interstitial water is appreciable (Item 6), ranging from 1 to 0.1 part per million.

5) Uranium is more concentrated in the less permeable rock. Reference to Item 11 shows a rough approximation of this correlation to the uranium in the total rock (Item 1) and the amount of the water-soluble uranium (Items 2 and 3). This correlation is more pronounced for water-soluble uranium calculated in interstitial water (Item 6). The few analyses available indicate a twentyfold difference of concentration of uranium in the interstitial water between the more and less

permeable specimens (Item 6 - Average). On the contrary, the soluble chloride content shows only an approximate twofold difference of concentration for the same specimens. Selective removal of the soluble uranium during coring is indicated, suggesting that the soluble uranium content in the formation may have been considerably more than found by the analyses of the cores.

6) In turn, the calculated radium content of the interstitial water (Item 10) may be considerably more than indicated.

7) The emanating power (Item 8) ranges from 1.23 to 12.39 percent, and averages 5.6 percent. (A total of 19 samples of Brown dolomite from this general area, including these samples and samples from a gas well in Sherman County, Texas, show a range in emanating power from 1.23 to 15.08 percent and an average of 7.4 percent.)

No asphaltite pellets were detected in the six analyzed samples.

Table 9.--Results of analyses of core samples from a gas well in Moore County, Texas

Item	Cable - tool core samples (Sample depths 3535' to 3607')					
	W-24	W-25	W-26	W-27	W-28	W-30
(1) U, total in rock,						
10^{-6} g U/g rock	51	9.4	9.7	3.5	4.2	2.4
Average 13.7×10^{-6} g U/g rock						
(2) U, water-soluble/U, total rock,						
10^{-3} g U/g U	.42	.036	1.04	.32	.25	.58
(3) U, water-soluble,						
10^{-8} g soluble U/g rock	2.16	.032	1.01	.111	.104	.138
(4) U, in residual oil,						
10^{-8} g oil-soluble U/g rock	< .024	< .023	< .013	< .019	< .019	< .05

Table 9.--Con't

	W-24	W-25	W-26	W-27	W-28	W-30
(5) U in residual oil, 10 ⁻⁶ gU/g oil	<1	<1	<1	<.1	<1	<5
(6) U (soluble) in interstitial water, after coring, 10 ⁻⁶ gU/ml Maximum, for computed loss of interstitial water.	2.34	.0512	1.60	.126	.0925	.0845
Minimum for assumed no loss of interstitial water.	1.68	.0462	1.44	.0964	.0732	.0749
Average 3 samples less than .1 millidarcy (Maximum) 1.36 x 10 ⁻⁶ ; (Minimum) 1.07 x 10 ⁻⁶						
3 samples more than .1 millidarcy (Maximum) .076 x 10 ⁻⁶ ; (Minimum) .0648 x 10 ⁻⁶						
(7) Ra in total rock, 10 ⁻¹² g Ra/g rock	1.86	1.33	.788	1.58	1.36	.921
(8) Rn emanating power, from total rock, percent	5.45	5.38	1.23	12.39	4.74	4.57
(9) U, times equilibrium, in total rock, factor (1.00 = equil.)	9.4	2.4	4.2	.75	1.05	.87
(10) Ra, assumed equilibrium with maximum U of item (7) in interstitial water, 10 ⁻¹² g Ra/l water	1460	17.5	540	100	111	74
Average 384 x 10 ⁻¹² g Ra/liter interstitial water (Bottom-water brine, same well, 350 x 10 ⁻¹² g Ra/liter water)						
(11) Permeability, millidarcies	<.1	.33	<.1	<.1	61.2	66.4
(12) Porosity, percent	8.6	2.7	2.8	6.5	12.1	22.2

Transient gas flow problem

Expressions have been obtained for pressure distribution, velocity, volume flux, and total cumulative production of a gas well as a function of time after opening a closed-down well. Static conditions prevail initially, and after opening, the well produces at constant well-bottom pressure. The effect of the nonlinearity in Muskat's isothermal gas flow equation is shown to be negligible. The calculations can be applied to problems involving short-term transient flow of gases, such as in experiments with radioactive tracers.

Plans

Careful chemical and radioactivity analyses and petrographic studies of all available drill samples will be continued. Stratigraphic and structural studies of gas-producing formations will be resumed. A final summary of the phase of the investigation dealing with the distribution of uranium, radium and radon between the dolomite rock matrix and the fluid contents of the porosity is awaiting the completion of measurements of the radium and radon content of various fractions of the samples. Undoubtedly, if the type of cores were secured that retain the interstitial water in an unaltered condition, none of the uranium or radium would be lost by flushing during drilling, and a more direct and satisfactory approach to this phase of the investigation would be possible.

It is planned to measure the radon content of gases and the radium content of brines and oil samples in a large number of oil and gas fields

scattered throughout the central states to determine the geographic extent of the phenomena found in the Panhandle gas field of Texas.

Calculations of permeability and porosity for use with transient gas flow equations will be continued.

MINERALOGIC AND PETROGRAPHIC SERVICE AND RESEARCH

by
E. J. Dwornik

Service

Identification

Public sample program, by E. Williams and R. Thompson

A total of 234 samples was received from the public during the report period and 270 letter reports sent out. Twenty percent of the samples showed significant radioactivity, i.e. above 0.005% equivalent uranium.

An additional group of 21 samples from foreign localities and commercial organizations, submitted through the AEC office in Washington were reported on. Sixty percent of this group showed significant to very high radioactivity necessitating more detailed radiometric, mineralogic study, chemical and spectrographic determinations.

Special samples, by R. Kellagher

Approximately 82 samples submitted by various Survey field parties engaged in uranium reconnaissance work were analyzed petrographically, petrologically and by X-ray spectrometer methods.

Monazite sands, by J. Stone

Since December 1, 1952, 921 samples from southeastern Monazite Belt have been analyzed and reported; an additional 411 have been counted but not yet calculated. An additional 600 samples are expected during the next three months and completion of the laboratory phase of the project before the end of the next report period is expected. A standard procedure for

weight percent determination of monazite sands has been established incorporating the cone sampler and abacus type counter (monacus) devised and built in this laboratory. This procedure may be used with minor modification on future requests for weight percent determinations of other heavy mineral concentrates.

X-ray

by C. L. Christ

A total of 635 powder patterns was run; 456 were on samples from laboratory projects, 153 on material from the A.E.C. and 26 on samples from Survey field personnel which were not submitted through a project. A total of 63 X-ray spectrometer runs were made; 43 on samples from field personnel and 20 from laboratory projects. A total of 215 X-ray spectrometer runs were made by members of the Florida phosphate and the Colorado Plateaus projects.

Electron microscopy

by E. Dwornik and C. Davis

During the report period 940 micrographs were made of 188 samples.

Approximately 35 samples were submitted by the personnel of the Florida phosphate project in connection with studies of clays associated with the deposits. Preliminary investigation of X-ray spectrometer patterns and electron microscope examination points to the occurrence of hectorite, previously unreported in the Florida deposits. Results of these studies will be included in a report on the fine-grained mineral phases occurring in the phosphorites.

Work was continued on the mineral fractions of the lignite with emphasis on separation of the allophane-like clay fraction and also on the secondary U-mineralization in asphaltic pelletal material from Oklahoma.

Size determinations were made on materials separated by the Stieff Air Concentrator (Stieff and Erickson, TEI-307) and also checks on the homogeneity of synthetic uranium minerals prepared by G. Jansen.

Confirmation of X-ray identification of clay minerals by the electron microscope in connection with Geochemistry and Petrology Branch service work has added greatly to the library of micrographs available for reference study of clays from various types of deposits. A new Puerto Rican locality for the occurrence of attapulgitite has been noted.

Research

Mineral separation and petrographic methods by R. Kellagher and P. Benson

The efforts of this project have been devoted to facilitating determinations of weight percent from grain counts and to eliminating the eye fatigue caused by constant use of the slide rule. To accomplish these objectives a machine was designed and built by Benson employing the principles of the nomogram (Berman, TEI-273). The mechanical operations involved proved much less fatiguing and nearly doubled the number of calculations made per day.

Continued effort toward speeding up the analysis of the tremendous backlog of monazite sands led to the purchase of a Toledo laboratory scale modified by a graph to read the percent a particular sieve fraction is of the total sample, and to the construction of an abacus type counter. The

counter consists of 10 rows of beads mounted on brass rods in a masonite backed wooden frame. Each row represents one of the constituents in the mineral assemblage and is underlain by a scale with divisions calibrated relative to the specific gravity of quartz. Weight units are then recorded as a volume count of a representative field is made. Multiples of the sieve fraction in weight units are counted in order to read directly the weight percent of the respective constituents on the scale.

The problem of selecting a representative field of a sieve fraction for grain counting was simplified by devising a "cone sampler". This sampler consists of 3 powder funnels and 3 inverted machined cones aligned alternately in a vertical column with one of the cones at the base. Surrounding the basal cone is a removable circular tray containing three sector shaped pans each including an arc of 9° or $2\frac{1}{2}\%$ of the area of the tray. A funnel is situated atop the column with its opening centered over the vortex of the uppermost cone. The sized material is poured through the centering funnel and is split successively three times. The lowermost cone spills the sand grains into the circular tray with three representative samples being captured in the small pans.

Tests on artificial samples and analyzed heavy-mineral concentrates have shown the splitter to be satisfactorily accurate and time saving. With minor modifications the splitter may be used on fine-grained sediments such as the lignites and phosphorites.

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

Work progressed during the past six months on the monograph "Mineralogy of Uranium", being prepared under the editorship of Rabbitt.

Clifford Frondel of Harvard University, who has a WAE appointment with the Geological Survey, is writing the chapter on description of properties; Judith Frondel, who also has a Survey WAE appointment, is preparing descriptive tables; George Switzer of the U. S. National Museum is writing chapters on the occurrence and association and the geographic location of the minerals; Theodore Botinelly is writing a chapter on characteristic methods of identifying uranium minerals in the field and laboratory. The several chapters are in different stages of preparation. The chapter on properties by Frondel is rapidly nearing completion and should be in the editor's hands by July 1, 1953. The other chapters are about two-thirds completed. Present plans call for the issuance of the monograph during fiscal year 1954.

During this period analytical work was completed by Frank Cuttitta on pure samples of vandendriesschite and masuryite. This type of analytical work consists of complete chemical analysis, and for most samples only 10 to 50 mg. are available for analysis. Analytical work is in progress on samples of diderichite, a new distinct phase referred to as green "uraninite", and schoepite from Beryl Mountain, New Hampshire. The results of this analytical work will be included in the monograph.

Judith Frondel continued her investigations of the hydrous uranium oxides. Her paper "Billietite and Becquerelite" (TEI-280, pp. 91-92), presented at the annual meeting of the Geological Society in Boston in November 1952 is being edited for publication in *The American Mineralogist*. The paper is being revised to include morphological data and more detailed X-ray data. X-ray, optical, and morphological studies have been completed on ianthinite and the so-called "mineral 'X' problem", a comparison of

masuryite, vandendriesschite, and mineral "X". Also, a study has been completed of the dehydration of natural schoepite, showing the phases obtained from room temperature to about 220° C. Reports on all this work are in progress.

The X-ray and thermal studies by Clifford Frondel on thorogummite (including nicolayite), mackintoshite, maitlandite, and hyblite (TEI-280, pp. 92-93), has been extended to include hydrothorite, zircon, and cyrtolite. A report on this work, "Hydroxyl substitution in thorite and zircon", by Clifford Frondel, is now being processed. The abstract follows:

The ill-defined thorite-like minerals thorogummite, nicolayite, hydrothorite, maitlandite, mackintoshite, and hyblite are found to be minor chemical variants of a single phase, for which the name thorogummite has priority. Thorogummite is isostructural with thorite and has virtually the same unit cell dimensions. It differs from thorite in being secondary in origin and formed by the alteration of primary thorium minerals including thorite itself, in occurring as fine-grained aggregates that are not metamict but crystalline, and in containing essential water. Chemically, thorogummite appears to be a hydroxyl-containing variant of thorite, ThSiO_4 , in which there is a serial substitution of $(\text{OH})_4$ for (SiO_4) with the formula $\text{Th}(\text{SiO}_4)_{1-x}(\text{OH})_{4x}$.

Cyrtolite apparently stands in an analogous relation to zircon.

Experimental work was completed by Clifford Frondel on a survey of the mineral composition of "gummite" pseudomorphs after uraninite. Work shows that the alteration of uraninite is sequential. Three zones of alteration are recognized, (1) an inner zone of anhydrous uranyl oxide including clarkeite and "green" uraninite; (2) an intermediate orange-red zone (conditional "gummite") composed chiefly of fourmarierite or vandendriesschite; (3) an outer silicate zone composed chiefly of uranophane, beta-uranophane, or kasolite. A report on this work is in progress.

X-ray spindles of 32 uranium minerals were sent on loan to the University of Arkansas so that additions could be made to their X-ray powder pattern library.

A second printing of 2000 copies of the second revised edition of "A glossary of uranium- and thorium-bearing minerals", by Judith Weiss Frondel and Michael Fleischer (U.S.G.S. Circ.-194) was made available for distribution in February 1953. The circular is available free on application to the U. S. Geological Survey, Washington 25, D. C.

GEOPHYSICAL PROSPECTING SERVICES AND RESEARCH ON METHODS

Development and maintenance of radiation
detection equipment
by W. W. Vaughn

About 150 commercially built portable scintillation survey meters are now used by the Survey and AEC. Sixty percent of these survey meters required modification to give optimum operation. So far the instruments have given excellent results and have definitely filled a need in the reconnaissance work for uranium ores. It is planned to purchase 103 more units for use in the uranium program this field season.

A method of electronically expanding the scale on the portable scintillation survey meter has been devised. In some cases the effective sensitivity has been increased five times normal, making possible readings of 0.0008 mr/hr. An instrument of this type is very useful in scanning drill cores and rock surfaces for minute concentrations of activity.

Field tests were made recently to compare the relative sensitivity of the various types of commercially available portable scintillation survey meters. The meters were first modified individually to meet our necessary standards of sensitivity, and the results of the tests showed that all meters indicated essentially the same radiation intensity from a given outcrop. The art of making a portable scintillation survey meter has been well perfected. However, it is exceedingly difficult to get a manufacturer to make instruments which represent this state of perfection. The non-linear characteristic--that is the deviation from the inverse square law of radiation from a radium needle--inherent in the scintillation and once thought to be a detriment, is now considered the merit factor when the instrument is used as a geologic tool.

The sensitivity of our portable scintillation survey meter when used for airborne surveying has been compared to more elaborate scintillation detection equipment installed in the survey aircraft. Tests performed in the Grand Junction area showed that the portable survey meter when properly modified is a satisfactory instrument for reconnaissance with light aircraft. Therefore an Esterline-Angus recorder driving circuit has been developed that can be plugged into a portable scintillation survey meter to make it a continuously recording device for use in light aircraft and automobiles.

A carborne scintillation survey meter using a transistor input system has been designed and constructed. The circuit uses two phototubes and crystal combinations, shielded by $\frac{1}{2}$ " of lead, and working into a common ratemeter. The output is recorded by an Esterline-Angus graphic ~~ammeter~~ meter. The chart is driven through a Metron variable reduction gear by the speedometer cable.

The portable gamma-ray logging reel has been redesigned. The new reel has a mercury-pool type of commutator, making it practical to use a scintillation probe as the detecting element. The reel capacity is 1000 ft. of RG-59/U cable. Field results prove the portable scintillation logging reel to be a satisfactory method of logging drill holes of 2 inches diameter or more.

The gamma activity in the Denver area has been monitored continuously during the recent nuclear weapons tests in Nevada. The highest readings were recorded from April 24 to May 1 with an average value of 0.08 mr/hr.

Airborne radioactivity surveying
by R. M. Moxham

Airborne surveys were undertaken in five eastern seaboard states and totalled 8,005 traverse miles. Surveys in the western states have been

temporarily postponed due to the nuclear weapons tests in Nevada.

A second aircraft for radioactivity surveying, a C-47 obtained on loan from the Air Force, is presently being structurally modified and outfitted. Scintillation detection equipment for the C-47, designed and built by the Division of Health Physics of the Oak Ridge National Laboratory, is essentially completed. It is anticipated that the second aircraft will be ready for preliminary flight tests by mid-July.

Several modifications of the scintillation detection equipment during the reporting period have resulted in a very appreciable improvement in operation and results. The principal change involved the replacement of the mechanical-switch scaler-type recording circuit by a counting-rate-meter circuit. The greater resolution of measurement offered by the scaler was found to be more than nullified by noise and mechanical difficulties directly attributable to the switching mechanism.

A simulated outcrop of carnotite ore will be completed by mid-July at the municipal airport at Grand Junction, Colorado. The dimensions of the slab will be 40 feet square by 6 inches thick, and the effective radiation intensity from the carefully sampled carnotite ore will be equivalent to that from a point source of about 50 mg. of radium. The simulated outcrop will serve, not only as a reference source for calibrating the response of any type of radiation detector, but also as source of known geometry and uranium content over which experimental measurements will be made to determine: (1) the effective attenuation of gamma radiation from ground sources by air, (2) the optimum values for time constant, spectral energy acceptance, and other related factors in detecting small naturally occurring sources, (3) the geometry and amount of shielding around the scintillation detectors required for maximum resolution of measurement, and (4) by placing additional

shielding over the simulated outcrop, the lower limits of detection of naturally occurring sources.

Areas surveyed

The areas surveyed from December 1, 1952 through May 31, 1953 shown on figures 33, 34, 35, and 36 are listed below:

<u>State</u>	<u>Area</u>	<u>Traverse miles</u>
Georgia	Atlantic ocean beach	105
North Carolina	"	310
South Carolina	"	200
Virginia	"	35
Florida	"	360
Florida	Madison, Hamilton, Duval, Dixie, Lafayette, Alachua, Union, Bradford, Clay, Sumpter, Marion, Orange Lake, Desoto, Charlotte and Collier Counties	6,620
North Carolina	Cleveland County	<u>375</u>
	Total	8,005

Discussion of significant areas

Atlantic Ocean beach survey:

The airborne survey of the Atlantic beach consisted of a single flight line from Cape Henry, Virginia to Miami Beach, Florida. The vertical projection of the flight line coincides approximately with the landward limit of the modern beach.

Twenty areas of abnormal radiation were detected during the beach surveys, apparently resulting from thorium-bearing minerals associated with surficial deposits of black sand (Areas A, and B, figs. 33-35). Several of

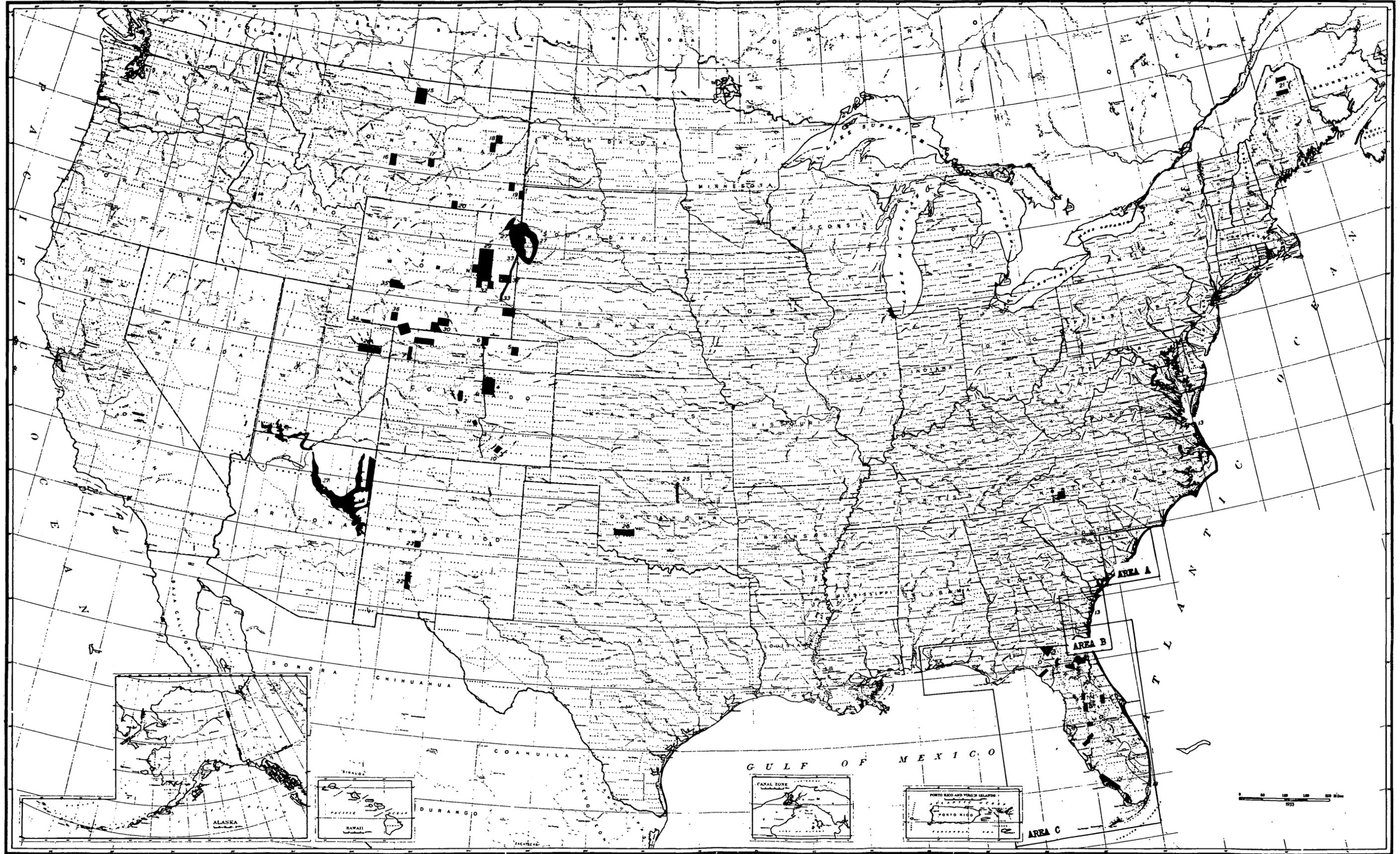


Fig. 33— Airborne radioactivity survey projects.

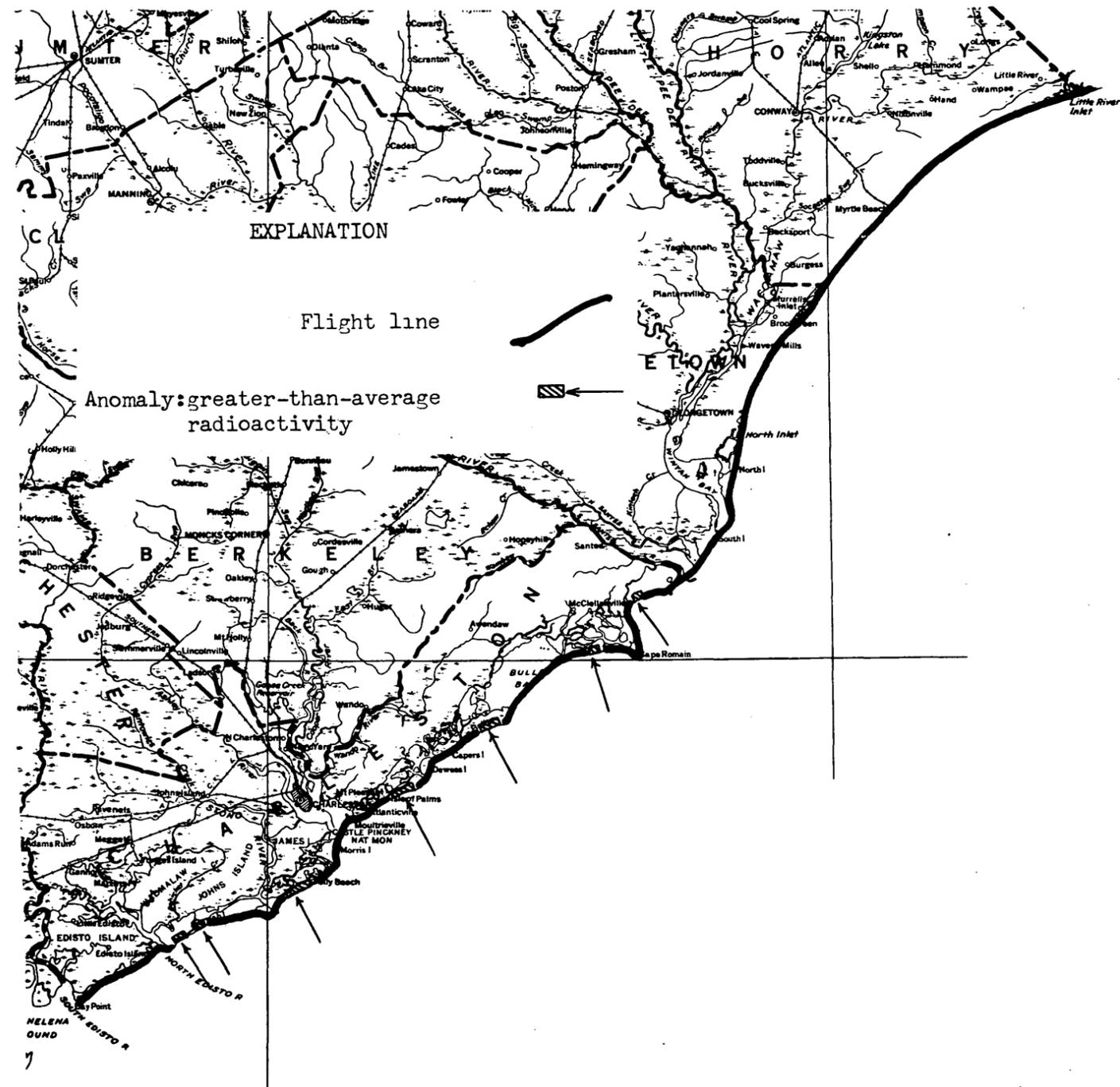
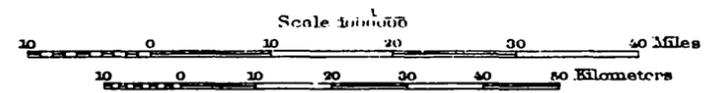


Fig. 34 — Airborne radioactivity surveys in South Carolina.



the deposits were previously known to be radioactive; others were not known heretofore. A small sample of surficial sands collected at the center of the anomalous area 5 miles southeast of Fernandina, Florida, contains 0.014 percent eU. A small sample collected from a layer of black sand, one foot thick at a depth of one foot below the surface, contains 0.041 percent eU. The radiation intensity at this locality was close to the average intensity for all anomalies recorded during the airborne survey of the beach.

Florida phosphate survey:

Ten areas, totalling approximately 1,650 square miles, were selected for surveying on the basis of geologic favorability for the occurrence of phosphate deposits. (See Area C, figs. 33 and 36.) Abnormal radioactivity was recorded in eight of the ten areas, and uraniferous phosphatic materials were found at two areas thus far investigated on the ground.

The area of greatest radiation intensity recorded during the surveys is in south-central Marion County. A brief field investigation was made of one of the anomalies in this area, in sec. 24, T. 17 S., R. 22 E., about 5 miles south of Belleview. Outcrops of leached phosphatic rock and float of similar material were found over an area of a few acres. One hand specimen, collected at a locality of maximum radiation intensity on the ground, contained 0.016 percent eU and about 75 percent silica, which, in regards to these two particular components, compares favorably with leached phosphate in the land-pebble field to the south.

The radioactivity anomalies in the valley of the Peace River apparently have resulted from concentrations of river pebble phosphate. A brief field investigation was made of the anomaly north of Arcadia. The phosphate nodules were found over an area of several tens of acres on the south shore

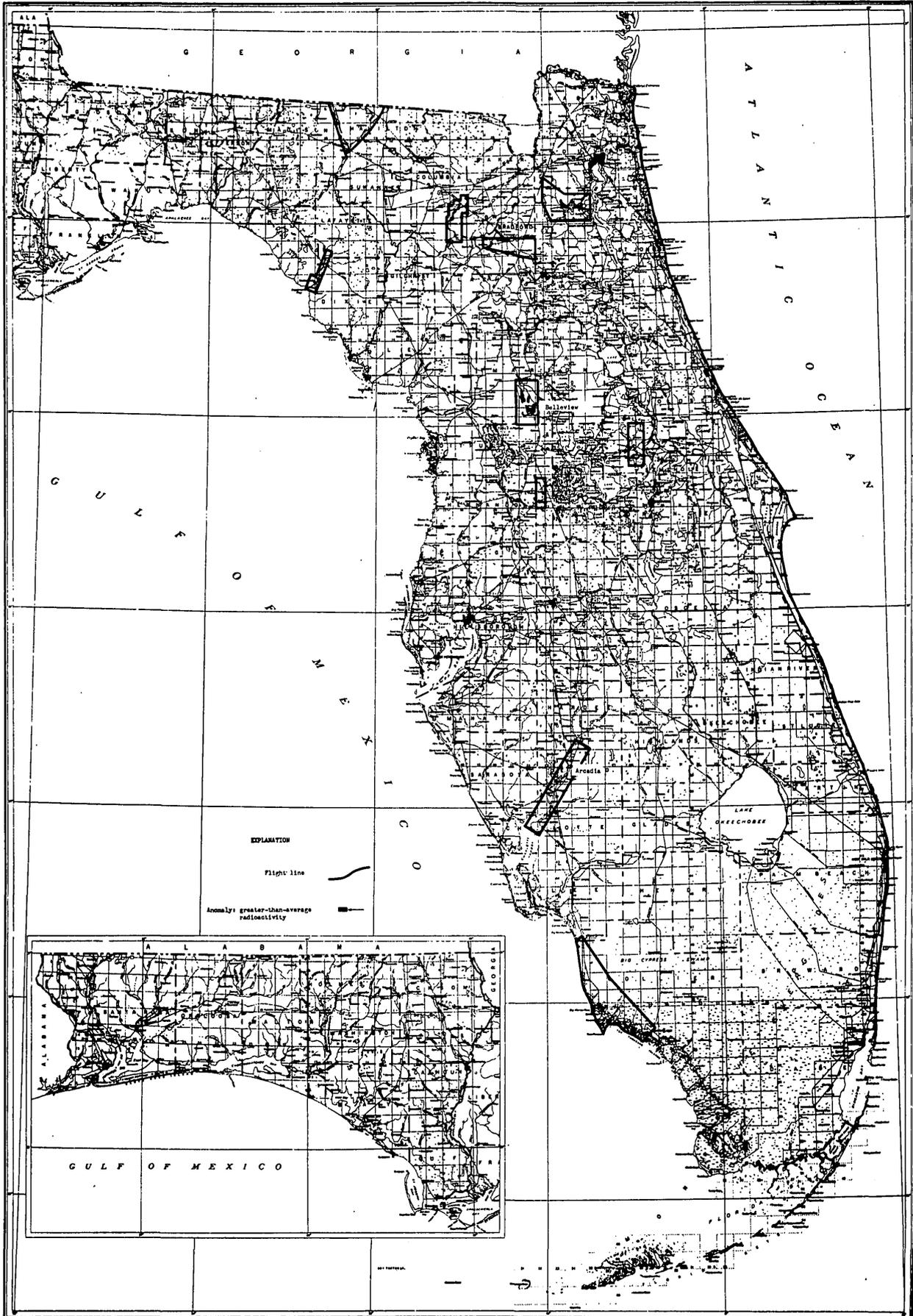


Fig. 36

of the river, and were locally concentrated in topographic lows, apparently as a result of wind action. Grab samples of material from three such local concentrations average 0.013 percent eU.

Shelby quadrangle:

The airborne survey of the Shelby quadrangle was largely of an experimental nature to determine: (1) whether there was any detectable radiation resulting from known placer deposits of monazite and (2) to what extent the airborne equipment might be used to locate areas of abnormal concentrations of monazite in bedrock. The Shelby survey has only been recently completed and the results have not yet been fully evaluated.

Absorption and scattering of gamma radiation

In conjunction with the comprehensive investigation of gamma radiation, we have considered one of the principal problems encountered in airborne radioactivity surveying, i.e., a semi-infinite source emitting to a tenuous medium.

We approach the problem in this manner: A transport equation in two media necessitates simultaneous solution in two media involving unknown boundary conditions which must lead to a "well-behaved" solution. We reduce this problem to that of two separate one-medium problems, taking advantage of the fact that the air would return very little radiation to the source. Thus, the first approximation would be that of a semi-infinite source emitting into a vacuum. We take this solution and introduce it into the transport equation for air. The resulting solution will be introduced into the transport equation for the source, whose ensuing solution will be introduced into the equation for air, and so on. However, due to the low electronic

density of air, a few iterations should suffice. Now, in general, the γ -ray scattering phenomenon is a very complicated energy dependent phenomenon, so we bracket it by two extremes, the "straight ahead" approximation and the isotropic approximation. In the former case, the preceding iteration will be rigorously true in the zero-order approximation as there is no return current. So if we show that the isotropic scattering yields useful solution in a few iterations, the real γ -ray problem certainly will. We are now engaged in solving the isotropic scattering problem.

Plans

The principal objective of the airborne radioactivity surveying is to find new and large areas of radioactive mineralization. Toward this end 34 areas, totalling about 22,700 square miles, have been proposed for airborne radioactivity surveying by Survey geologists. These areas were selected on the basis of geologic favorability determined by current hypotheses of the origin, transportation and deposition of uranium and thorium.

The areas proposed for surveying are shown on figure 33 and are listed in table 10.

Experimental measurements over the simulated outcrop in Grand Junction are planned during July and August. The theoretical studies on a semi-infinite source emitting to a tenuous medium will be prepared for machine computation by the AEC Computer Facility at New York University.

Surveys to be undertaken during the 1953 field season will tentatively include the Miller Hill area, Wyoming (area 30, fig. 33), the South Dakota portion of the Black Hills (27), a portion of the Vermillion Cliffs area in Arizona and Utah (1, 37), the South Park (2) area, Colorado, and the Myton area, Utah (28).

Table 10.--Areas proposed for airborne radioactivity surveys
Revised 3/1/53

<u>State</u>	<u>County</u>	<u>Area</u>	<u>Area no., fig.</u>	<u>Objective</u>	<u>Square Miles</u>
Arizona	Coconino Mojave Navajo Apache	Vermillion Cliffs (see Utah)	1, 37	Survey of Chinle and Shinarump formations	5,350
Colorado	Park	South Park	2	General radio- activity recon- naissance	200
		Front Range	3	" "	45 (1 flight line)
	Douglas Elbert El Paso	Castle Rock	4	Survey of Eocene coal-bearing rocks	875
	Weld	Buckingham	5	Survey of Laramie Pierre and Fox River formations	215
	Larimer	North Fort Collins	6	Survey of Permian to Cretaceous sediments	215
	Moffat Rio Blanco	Coyote Basin	7	Survey of Tertiary Rocks including Browns Park for- mation	200
	Moffat	North Craig	8	Survey of Browns Park and Lance formations	500
	Moffat	Hiawatha	9	Survey of Wasatch formation	485
	Las Animas	Model Dome	10	Survey of area be- tween Model and Thatcher Domes	400
	Fremont	Wet Mountains Custer Huerfano	11	Reconnaissance for thorium mineraliza- tion	350
Idaho	Valley	Long Valley	14	Survey of monazite placers	80

Table 10.--Areas proposed for airborne radioactivity surveys (cont'd.)

<u>State</u>	<u>County</u>	<u>Area</u>	<u>Area no., fig.</u>	<u>Objective</u>	<u>Square Miles</u>
Maine	Aroostook	Devonian Belt	21	Survey of Devonian volcanic rocks	370
Montana	Blaine	North Bear Paw	15	Survey of the Judith River formation	770
	Wheatland Sweetgrass	Two Dot	16	Survey of coal-bearing rocks, Paleozoic to Eocene	300
	Musselshell	Bull Mountain Syncline	17	Survey of the Ft. Union formation	215
	Prairie McCone Dawson	Sheep Mountain Syncline	18	Survey of coal-bearing Paleozoic rocks	430
	Carter	Ekalaka-Midland	19	Survey of Paleocene coal-bearing rocks	430
	Big Horn	Wolf Mountain	20	Survey of the Wasatch and Ft. Union formations	215
New Mexico	Sierra	Sierra Caballos	22	General radioactivity survey	450
	Socorro	San Acacia	23	General radioactivity survey	140
Oklahoma	Pawnee Payne	Pawnee	25	Reconnaissance along east flank of Nemaha uplift	240
	Kiowa	Wichita Mountains Caddo	26	Reconnaissance for uraniferous hydrocarbons in Permian redbeds	500
South Dakota	Pennington Custer Fall River	Black Hills (see Wyoming)	27	Survey of Paleozoic and Mesozoic rocks of the Black Hills uplift	1,600
Utah	Duchesne	Myton	28	Survey of Cretaceous and Eocene rocks	1,500

Table 10.--Areas proposed for airborne radioactivity surveys (cont'd)

<u>State</u>	<u>County</u>	<u>Area</u>	<u>Area no., fig.</u>	<u>Objective</u>	<u>Square Miles</u>
Utah (cont'd)	Washington Uintah	Vermillion Cliffs (see Arizona)	1	Survey of Chinle and Shinarump formations	540
	Kane				
Wyoming	Johnson Converse	Powder River Basin	29	Survey of the Wasatch formation	1,750
	Crook Weston	Black Hills (see S. Dakota)	27	Survey of Paleozoic and Mesozoic rocks of the Black Hills uplift	1,200
	Carbon	Miller Hill	30	Survey of the Browns Park formation	700
	Goshen	Goshen Hole	31	Survey of the Lance formation	450
	Converse	Pine Ridge Escarpment	32	Survey of Jurassic and Paleocene rocks along Pine Ridge Escarpment	700
	Weston Niobrara Goshen	Hartville- Newcastle	33	Survey of the Creta- ceous and Tertiary along uplift between Hartville and New- castle	700
	Uinta	West Lonetree	34	Survey of the Bridger and Browns Park for- mations	50
	Sublette Fremont	Tabernacle Buttes	35	Survey of Eocene and pre-Cambrian rocks	360
	Sweet- water	Aspen Mountain	36	Survey of southwest flank of Washakie Basin	270

Physical behavior of radon
by A. S. Rogers

As part of the study of the physical behavior of radon undertaken to determine how and why radon moves in rocks and soils, a systematic study of phase relationships of radon in various liquids and gases was initiated to verify existing data. Equipment for radon measurements using an all-tygon tubing system with glass joints has been constructed and placed in operation at the University of Utah in Salt Lake City. The adsorption of radon by tygon tubing has been investigated carefully and is negligible (less than 0.5 percent) for four-foot lengths.

The distribution with varying temperature of radon (distribution ratios) between water and several gases is being investigated. The results to date are:

1. The distribution of radon between distilled water and air does not depend on radon content through a range of 13 to 5,250 micro-microcuries per liter (fig. 37).
2. Equilibrium distribution of radon is achieved between water and air phases of equal volumes by shaking the mixture between 10 and 30 seconds. A shaking period of 10 seconds shows a deviation of 12 percent from equilibrium distribution. Equilibrium is established after shaking the mixture for 30 seconds.
3. Distribution ratios through a temperature range of 15 degrees show a maximum deviation of plus 2 percent over the ratios reported by Paneth and Hevesy, Kofler, and Boyle (fig. 37).
4. Distribution ratios obtained by two measurements in the water-natural gas system are in agreement with the distribution ratios obtained by measurements in the water-air system (fig. 37).

Distribution Ratio for Radon

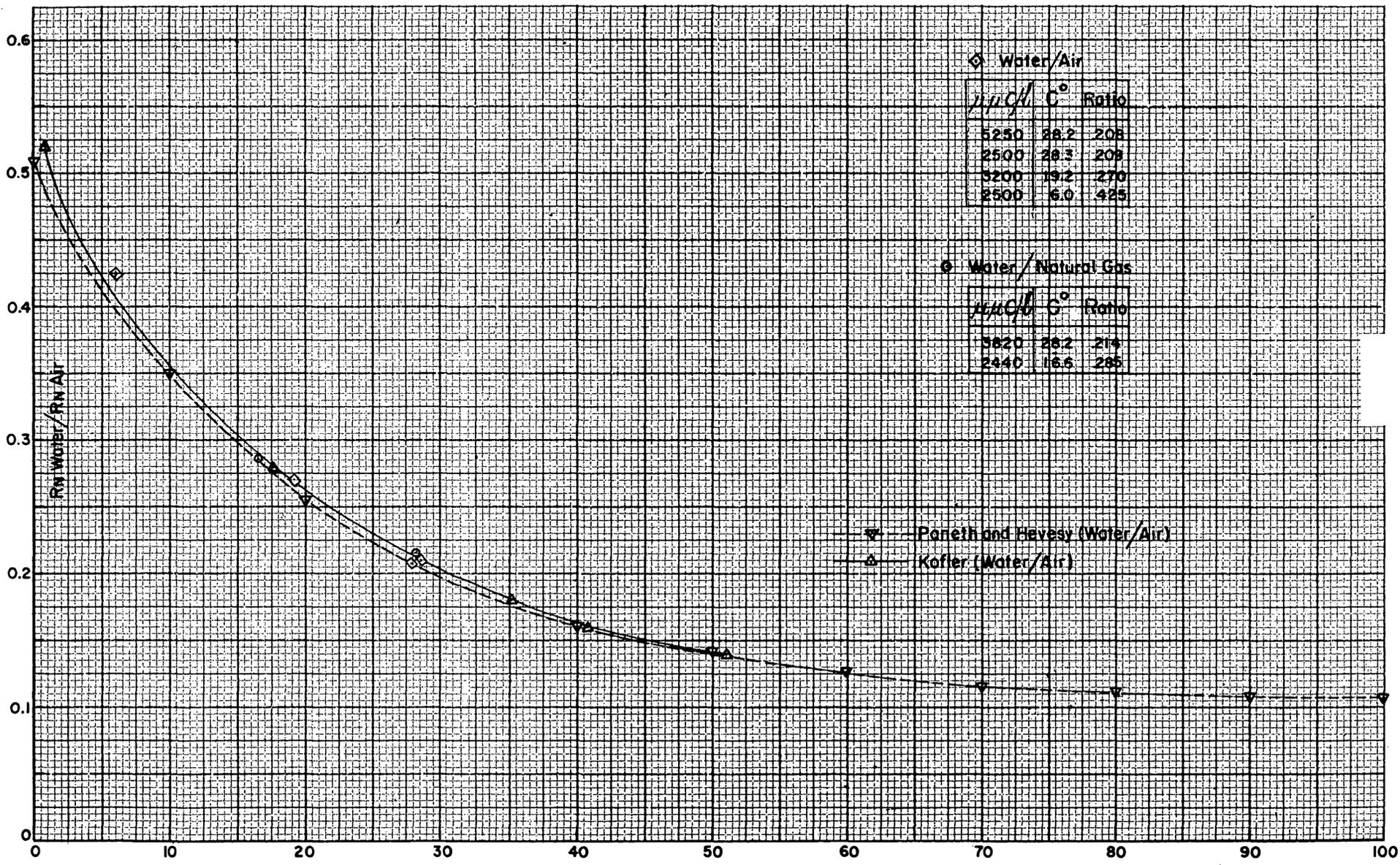


Fig. 37 — Temperature in degrees centigrade.

5. Preliminary data show no differences in distribution of radon in any combinations of air, argon, nitrogen, distilled or domestic waters.

Radium determinations (table 11) were made on 19 bottom-hole brine samples in connection with radon investigations in the Panhandle and Hugoton gas fields of Texas, Oklahoma and Kansas. Unfortunately, because the brine samples had not been properly acidified, radium plated out on the glass in some of the sample bottles, as shown by the excess in some samples of the radon in brine over the radium in brine (table 11). Arrangements have been made to collect more brine samples, properly acidified, to prevent such plating out. Some samples (table 11) show an excess of radium in brine over radon in brine probably because of radon loss to the atmosphere on transferring brine to the radon boiler.

Some surface streams draining the Wasatch Mountains adjacent to Salt Lake City, Utah, show high radon content, ranging from 14 to 28.5 micro-microcuries per liter. These streams drain a thick sequence of Triassic and Jurassic sediments, including the Morrison and Shinarump formations (or equivalents thereof), but the radon content in these streams is "considerably higher" than that reported for water samples from the Dolores and San Miguel Rivers draining the uraniferous Morrison and Shinarump formations in the Colorado Plateau. An attempt will be made to trace the radon to its source.

A water well on the University of Utah campus has a radon content of 321 micromicrocuries per liter.

The systematic study of phase relationships of radon in water and various gases will be continued. Radium measurements will be made on additional bottom-hole brine samples from the Panhandle and Hugoton gas fields of Texas, Oklahoma, and Kansas, and the distribution ratios between brine and natural gas determined. Measurements of the radon content of air in mines and drill holes are also planned.

Table 11.---Brine samples from Panhandle and Hugoton gas fields

<u>Well</u>	<u>County</u>	<u>State</u>	<u>pH</u>	<u>Radon in brine 1/ mm curies l</u>	<u>Radium in brine 10⁻¹² gm/l</u>	<u>Radium in sludge 2/ 10⁻¹² gm/l</u>
Neild-D	Moore	Texas	6	195	~1	3.9
Ola #1	Moore	Texas	5.5	110	350	-
Moore 66 #3	Moore	Texas	5.5	22.2	18.8	-
Gator	Hansford	Texas	4	558	1060	227 3/
McLaughlin #1	Hartley	Texas	5.5	115	119	6.5
Property #1	Sherman	Texas	-	-	90	-
Colwell #1	Moore	Texas	7	61.3	11.2	8.8
Tina #1	Sherman	Texas	5	116	171	5.6
Pierre #1	Sherman	Texas	6.5	59.4	5.6	7.2
Renner #1	Sherman	Texas	5.5	28.9	83	4.7
Teddy #1	Hartley	Texas	7	8.7	6.0	2.3
Armour #1	Texas	Oklahoma	4.5	17	96	-
Deakin #1	Texas	Oklahoma	4.5	25.2	119	-
Wild Bill #1	Hutchinson	Texas	5.5	5.3	15.1	-
Ansley #1	Moore	Texas	6	6.3	6.1	-
Mundy #1	Texas	Oklahoma	4.5	27.0	183	-
Borah #1	Texas	Oklahoma	5.5	20.0	112	-
Nusbaum #1	Sherman	Texas	5	61.2	39.5	-
Wacker #1	Texas	Oklahoma	1	39.4	89.0	-

1/ Radon measured after the sample was at least three weeks old. Part of the radon was lost when the sample was exposed to air while measuring the volume of the sample and pouring it into the radon boiler.

2/ Radium in the sludge that settled to the bottom of the sample bottle.

3/ Radium in suspension in the liquid sample. Part of the liquid was filtered to separate the sludge.

Absorption and scattering of gamma radiation
by A. Y. Sakakura

The primary objectives of this project are: (1) the reduction of data taken at the National Bureau of Standards in simulated drill holes, and (2) to solve the transport equation for gamma-ray diffusion in geometries of geologic interest.

Regarding the first objective, re-examination of data reveals the need for repeating some of the experiments. The results reported in the previous semi-annual report are still qualitatively correct, but are of insufficient accuracy for certain calculations.

As for the second objective, it must be borne in mind that solutions of mathematical problems are essentially those of trial and error, the choice of proper approach being dependent on the judgment of the researcher.

A new mode of solution has been found to attack the problem of drill hole geometries. The method consists of expanding the gamma-ray distribution functions in surface harmonics (following Spencer and Fano) and eliminating the source function through introduction of solutions of simpler problems. The rest of the distribution function then satisfies a certain set of homogeneous equations, whose solutions exist if the secular determinant of the coefficients vanish. The number of roots of the determinant must naturally be twice the number of equations satisfied at the boundary. It is found that, in the case of polynomial expansion of finite degree in infinite source geometry, only odd order approximations have unambiguous solutions. In the case of a plane source with drill hole through it, no finite order approximation yields unambiguous results. The requirement on the latter problem is then that it must reduce to the infinite source problem in the limit when the plane source becomes an infinite one. To be sure these are approximations

based on scattering and absorption cross-sections being independent of energy, but these simplified problems must be solved in order that actual solutions can be most advantageously solved numerically in a computing machine. Plans are now being made to formulate the problem in a manner suitable for machine solution. Incidentally, the simplified solution yields a result in accord with experiment that the counting rate increases linearly with hole size with constant source density.

Another theoretical problem under investigation is the problem met in airborne surveying--intensity from plane sources. The solution consists in iterating the solution for radiation into vacuum, as air returns very little current into the source, in the exact transport equation. This problem can be solved numerically long before the drill hole problem. Plans are now made to set up the problem for machine computation. (See section under Airborne radioactivity surveying.)

Gamma-ray logging
by K. G. Bell

Routine logging service

Routine gamma-ray logging of drill holes was done during the past six months in the same manner as during previous periods. This logging results in: (1) quick quantitative appraisals of the uranium contents of ore-bearing formations, and (2) the detection of uranium daughter products found down dip from ore bodies that provide a guide to ore.

Colorado Plateau

The number, distribution, and footage of holes logged during the period of November 23, 1952 to May 17, 1953, are as follows:

<u>EXPLORATION AREA</u>	<u>NO. OF HOLES</u>	<u>FOOTAGE LOGGED</u>
Atkinson Mesa	165	44,078
Beaver Mesa	4	554
Club Mesa	12	2,474
Georgetown Group	5	878
Gypsum Valley	134	19,721
Jo Dandy	38	8,259
La Sal Creek	6	1,115
Long Park	160	37,834
San Miguel Bench	159	29,725
Spring Creek Mesa	101	26,672
Summit Group	2	403
Yellow Cat	<u>206</u>	<u>28,687</u>
	992	200,400

Three holes having an aggregate footage of 412 feet which were drilled by the U. S. Vanadium Corporation in the Jo Dandy area, and five holes having an aggregate footage of 372 feet which were drilled by independent operators in the Beaver Mesa area, were logged.

Tyrone and Blackhawk districts, N. Mex.

Gamma-ray logs were made of 168 holes having an aggregate footage of 80,287 feet which were drilled by the Phelps-Dodge Corp. on a copper prospect at Tyrone, Grant County, N. Mex. Several of these holes showed significant radioactivity anomalies. It was determined that some of these anomalies were caused by radon accumulating in the holes. Three holes having an aggregate footage of 3,000 feet which were drilled in the Blackhawk district, Grant County, N. Mex., by the Phelps-Dodge Corp. were logged. Six holes having an aggregate footage of 1,215 feet which were drilled in the White Signal district, Grant County, N. Mex., by other prospectors were logged.

Interpretation and processing of data

Grade estimates in terms of eU_3O_8 were determined from anomalies appearing on gamma-ray logs of the following listed holes:

<u>EXPLORATION AREA</u>	<u>HOLE NUMBERS</u>
Atkinson Mesa	122 - 359, inclusive
Blue Mesa	1 - 284, inclusive
Carrizo Mountains	1 - 24, inclusive
Club Mesa	645 - 656, inclusive
Ellison Group	1 - 41, inclusive
Georgetown Group	1 - 72, inclusive
Gypsum Valley	180 - 316, inclusive
Jo Dandy	121 - 188, inclusive
Long Park	1 - 816, inclusive
Lower Group	1 - 91, inclusive
San Miguel Bench	122 - 308, inclusive
Spring Creek Mesa	1 - 152, inclusive
Yellow Cat (Core drill)	325 - 516, inclusive
Yellow Cat (Wagon drill)	<u>167 - 722, inclusive</u>
	2,770 holes

Development

One gamma-ray logging unit which was equipped with a 400-foot capacity cable reel has been modified and the reel replaced with one having a capacity of 2,000 feet of cable.

The ratemeter circuit used with the Survey's gamma-ray logging equipment has been modified with the objective of improving its stability which makes possible increased accuracy of determinations of grade of ore exceeding 1.0 percent eU_3O_8 . Personnel from the Radiation Instrument Shop have done most of this work. It will be necessary to make corrections for a part of the calibration chart used to make grade determinations from gamma-ray anomalies appearing on drill hole logs.

RESOURCE STUDIES

Resource studies embracing the whole scope of the program have as their objectives: (1) compilation of data on the distribution, size, quality and other characteristics of domestic resources of uranium and thorium, (2) analysis and collation of these and other data to develop an understanding of the principles of occurrence as a guide to search for new deposits, and (3) maintenance of a central reservoir of information pertaining to uranium and thorium.

A principal continuing task during the interval since December 1, 1952, has been the abstracting of resource data contained in Survey, AEC, and contractor reports and issuing these data on cards to two offices each of the Survey and AEC. During the period the large backlog of abstracting has been reduced so that it is now measurable as an accumulation of months rather than years. Final copies of cards have been issued as facilities permitted.

Photographic and stickpin copies have been made of a map of the United States on a scale of 1:2,500,000 showing localities that had been examined for uranium up to June 30, 1952. These have been distributed to New York and Washington offices of the Division of Raw Materials and to Washington and Denver offices of the Geological Survey.

Plans have been formulated for and many initial steps completed to assemble an enlarged resource group staff so that the appraisal of resources synthesis of information into useful principles may be more effectively prosecuted. The group will be centered in Denver and transfer of some the staff and functions from Washington began in May.

Service and staff work continued to occupy a large part of the project effort during the period.

In the next six-month period, staff for the enlarged group will assemble as other commitments are finished, and the group should be essentially complete by the end of the period. Senior members of the group will be specialists or potential specialists in uranium and thorium geology or in general subjects of wide application such as geochemistry and natural radioactivity.

The present nucleus staff will be occupied principally with problems of organization for the enlarged group, with continued preparation of locality resource cards and with bringing data for the United States locality map up to date and adapting it for publication as a minerals resource map.