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U. S. DEPARTMENT OF THE INTERIOR

# GEOLOGIC INVESTIGATIONS OF RADIOACTIVE DEPOSITS, 1942–1960

## A Bibliography of U. S. Geological Survey Publications on the Geology of Radioactive Deposits

By
Andrew Brown

This report is preliminary and has not been edited for conformity with Geological Survey format and nomenclature

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GEOLOGY AND MINERALOGY

UNITED STATES, DEPARTMENT OF THE INTERIOR

GEOLOGICAL SURVEY.

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## A Bibliography of U. S. Geological Survey publications on the geology of radioactive deposits*

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

CONTENTS

# INTRODUCTION

This report, the last of a series of periodic reports covering investigations made by the U. S. Geological Survey on behalf of the Divisions of Raw Materials and Research of the U. S. Atomic Energy Commission, is a bibliography of Geological Survey publications stemming from the Survey's investigations of radioactive materials and deposits since 1942. The listings, which are complete as of November 30, 1960, include not only reports on investigations carried on under AEC sponsorship, but those on uranium and thorium geology and related subjects financed from the Survey's direct appropriation.

The investigations reported upon in this bibliography are part of the most intensive study of any element or group of elements ever undertaken by any nation. At the outset of World War II uranium and thorium were hardly more than scientific curiosities, though their fissionable qualities had been known for many years. Uranium minerals had been used as a source material for the extraction of radium, and uranium salts were used principally as a pigment for coloring glass and chinaware. The most important use for thorium was in mantles for gas lamps. The uranium used in the first atomic bombs was acquired from foreign sources, and when the Atomic Energy Commission was created in 1946, it was generally believed that the uranium reserves and resources of the United States were small indeed. The fact that within less than a decade the picture changed from one of apparent scarcity to one of abundant supply is an accomplishment in which the Commission, the Survey, and the other agencies and groups that participated in the program can take justifiable pride.

From its beginning the Division of Raw Materials was charged with the responsibility of finding and producing enough uranium ore within the United States to meet the rapidly increasing needs of the Nation's atomic energy program. For geologic advice and assistance the Division called upon the Survey, which previously had made studies of fissionable elements under its strategic minerals program and, during the war, for the Manhattan Engineer District. On July 1, 1947, the Division of Raw Materials began its sponsorship of a program on the geology of uranium, thorium, and other elements of interest to the atomic energy program. This sponsorship continued until June 30, 1958. Since that time, many projects have been completed, others continued, and a number of new investigations started, all under the Survey's direct appropriation.

The program of the Division of Raw Materials was at first essentially of the "rock-in-the-box" type, aimed at discovering and mining uranium deposits of commercial size as rapidly as possible. It soon became apparent to the Survey that if its uranium and thorium investigations were to produce optimum results, fundamental studies of the geology, mineralogy and geochemistry of the fissionable elements were essential. The Division of Raw Materials widened the scope of its program to include long-range geologic studies, and on July 1, 1951, the Division of Research began sponsorship of a number of basic research studies. This sponsorship continued until June 30, 1960.

Prior to 1954 security restrictions prevented the Survey from publishing many of its findings in the fissionable materials program. In 1954, however, the major part of the Survey's geologic and related material was declassified and publication became possible. The

Proceedings of the First United Nations International Conference on the Peaceful Uses of Atomic Energy (Geneva, Switzerland, 1955) contained 64 papers by Survey authors, which were published by the Survey in 1956 as chapters in Professional Paper 300. Since that time many more reports have been published and the rate of publication has been constantly accelerated.

Since 1947 the Survey has informed the Commission of the progress of its investigations by means of administrative reports in the Trace Elements Series. These were either Trace Elements Investigations Reports (TEI's), most of which were fairly comprehensive discussions of certain subjects or areas, or Trace Elements Memorandum Reports (TEM's), which were short papers on small areas or problems. The TEI series included periodic reports which were issued monthly and quarterly until 1952 and semiannually from 1952 through 1959. TEI and TEM reports were issued without intensive technical review and editing and are not considered formal Survey publications. Much of the material transmitted to the Commission in that form, however, was incorporated later into Survey publications in the Professional Paper, Bulletin, Circular, and the various Map series.

From 1947 through November 30, 1960, a total of 1,783 TEI and TEM reports were transmitted to the Divisions of Raw Materials and Research. Of these, 162 have been reissued by the Commission and made available to the public through the Office of Technical Services of the U. S. Department of Commerce. Among the Reports so reissued are all of the Semiannual Reports beginning with TEI-330, which covers the period December 1, 1952 to May 31, 1953. In addition to Trace Elements Reports

reissued by the Commission, about 160 such reports have been made available for public inspection by release in the Survey's open files.

Formal Survey publications on the geology of fissionable materials which are listed in this bibliography include:

23 Professional Papers, including two summary publications which are explained below.
160 Bulletins
95 Circulars
18 Geologic Quadrangle (GQ) Maps
145 Field Studies (MF) Maps
220 Miscellaneous Investigations (I) Maps, including 216 photogeologic maps.
8 Geophysical Investigations (GP) Maps
6 Coal Investigations (C) Maps
3 Oil and Gas Investigations (OM) Maps
1 Mineral Resources (MR) Map
3 Preliminary Maps

The summary publications referred to above are Professional Paper 300, published in 1956, and Professional Paper 400-B, published in 1960. The citation to Professional Paper 300 is:

> Page, L. R., Stocking, H. E. (AEC), and Smith, H. B., 1956, Contributions to the geology of uranium and thorium by the U. S. Geological Survey and Atomic Energy Commission for the United Nations International Conference on the Peaceful Uses of Atomic Energy, Geneva, Switzerland, 1955.

In this bibliography, for the sake of brevity, the complete eitation is not given for the chapters in Professional Paper 300; instead they are cited as "Professional Paper 300", followed by the page numbers, the names of the authors, the date, and the titles of the chapters. The same procedure is followed in citing chapters in Professional Paper 400-B, the citation to which is:

> Geological Survey Research 1960: Short papers in the geological sciences.

In some sections of this bibliography two or more publications bearing the same, or essentially the same, title are listed. In such

cases one of the citations is usually to a Circular or to a chapter in Professional Paper 300. The reason for this apparent duplication is that prior to 1955 many Circulars were issued to make certain information available rapidly, and the material in them was later expanded for publication in the Professional Paper or Bulletin series. Most of the chapters in Professional Paper 300 are summaries, prepared for the Geneva Conference, of larger and more comprehensive reports that were in preparation when the Conference was held.

In addition to the reports published by the Survey itself and listed in this volume, Survey authors have published a total of 228 abstracts and 368 full-length papers stemming from the uranium program in scientific journals devoted to different phases of the earth sciences. These journal papers, like the Survey's own publications, have contributed substantially to the knowledge of uranium geology.

Entries in this bibliography are arranged under the following main headings:

General publications on uranium and thorium
Reconnaissance for uranium and thorium
Uranium in sandstone-type deposits
Uranium in carbonaceous materials
Uranium in phosphates
Uranium in limestones
Investigations of thorium and related elements
Beryllium investigations

Each publication is listed under the category of its major interest. As examples, publications on such subjects as geophysics, mineralogy or geochemistry, if of a general nature or applicable to the Nation or a large part thereof, are listed under "General Publications", whereas those on areas in the Colorado Plateau are cited under "Uranium in sandstone-type deposits". Similarly, a large number of publications

stemming from the reconnaissance program describe uranium occurrences or deposits in specific environments; these are listed under the rock type in which they occur, rather than under the general "Reconnaissance" heading. Admittedly, some reports fall into a gray zone between the general and specific categories, but these are relatively few in number and a minimum of arbitrary decisions as to the proper grouping have been necessary.

# GENERAL PUBLICATIONS ON URANIUM AND THORIUM

This section includes bibliographies on uranium and thorium, and publications of a general nature in the fields of geology, mineralogy, geophysics, geochronology, tectonics, and analytical methods.

## Bibliographies

*Circular 281: Curtis, Diane, and Houser, S. S., 1953, Bibliography of U. S. Geological Survey Trace Elements and related reports. 21 p. (superseded by Bulletin 1019-B)

Bulletin 1018: Harris, R. A., Davidson, D. F., and Arnold, B. P., 1954, Bibliography of the geology of the western phosphate deposits. 89 p.

Bulletin 1019-B: Wallace, J. H. and Smith, H. B., 1955, Bibliography of U. S. Geological Survey Trace Elements and related reports to June 1, 1954. 82 p. (superseded by Bulletin 1107-A)

Bulletin 1019-F: Buck, K. L., 1957, Selected bibliography of thorium and rare-earth deposits in the United States including Alaska. 25 p., 1 pl., 1 fig.

Bulletin 1059-A: Kehn, T. M., 1957, Selected annotated bibliography of the geology of uranium-bearing coal and carbonaceous shale in the United States. 28 p., 1 fig.

Bulletin 1059-B: Curtis, Diane, 1957, Selected annotated bibliography of the geology of uranium-bearing phosphorites in the United States. 30 p., 2 figs.

Bulletin 1059-C: Melin, R. E., 1957, Selected annotated bibliography of the geology of sandstone-type uranium deposits in the United States. 117 p., 1 fig.

Bulletin 1059-D: Jones, H. N., 1958, Selected annotated bibliography of the geology of uraniferous and radioactive bituminous substances, exclusive of coals, in the United States. 27 p., 1 pl.

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* An asterick preceding the number indicates that the publication listed is out of print.

Bulletin 1059-E: Curtis, Diane, 1958, Selected annotated bibliography of the uranium geology of igneous and metamorphic rocks in the United States. 58 p., 1 pl.

Bulletin 1059-F: Fix, C. E., 1958, Selected annotated bibliography of the geology and occurrence of uranium-bearing black shales in the United States. 63 p., 1 pl.

Bulletin 1107-A: Soister, P. E. and Conklin, D. R., 1959, Bibliography of U. S. Geological Survey reports on uranium and thorium, 1942 through May 1958. 167 p.

Bulletin 1059-G: Dean, B. G., 1960, Selected annotated bibliography of the geology of uranium-bearing veins in the United States. 23 p., 1 pl.

## Geology

Circular 220: 1952: Selected papers on uranium deposits in the United States. 31 p., 23 figs. Contains:

Kalser, E. P. and Page, L. R., Distribution of uranium deposits in the United States.

King, R. U., Moore, F. B., and Hinrichs, E. N., Pitchblende deposits in the United States.

Wilmarth, V. R., Bauer, H. L., Jr., Staatz, M. H., and Wyant, D. G., Uranium in fluorite deposits.

Stugard, Frederick, Jr., Wyant, D. G., and Gude, A. J., 3rd, Secondary uranium deposits in the United States.

Wyant, D. G., Beroni, E. P., and Granger, H. C., Some uranium deposits in sandstones.

Gott, G. B., Wyant, D. G., and Beroni, E. P., Uranium in black shales, lignites, and limestones of the United States.

Bulletin 1027-G: Norton, J. J. and Schlegel, D. M., 1955, Lithium resources of North America. 26 p., 1 fig.

Map MR-2: Schnabel, R. W., 1955, The uranium deposits of the United States. Scale 1:5,000,000.

Professional Paper 300, p. 5-12: Stocking, H. E. (AEC) and Page, L. R., 1956, Natural occurrence of uranium in the United States - a summary.

_____, p. 17-25: Klepper, M. R. and Wyant, D. G., 1956, Uranium provinces.

_____, p. 27-40: Butler, A. P., Jr. and Schnabel, R. W., 1956, Distribution and general features of uranium occurrences in the United States.

_____, p. 41-43: McKelvey, V. E. and Everhart, D. L. (AEC), 1956, Summary of hypotheses of genesis of uranium deposits.

_____, p. 321-327: Finch, W. I., 1956, Uranium in terrestrial sedimentary rocks of the United States exclusive of the Colorado Plateau.

_____, p. 381-386: Bell, K. G., 1956, Uranium in precipitates and evaporites.

_____, p. 477-481: McKelvey, V. E., 1956, Uranium in phosphate rock.

Bulletin 1046-F: Klepper, M. R. and Wyant, D. G., 1957, Notes on the geology of uranium. 62 p.

Map I-299: Finch, W. I., Parrish, I. S., and Walker, G. W., 1959, Epigenetic uranium deposits of the United States. Scale 1:5,000,000.

Professional Paper 354-G: Bell, K. G., 1960, Deposition of uranium in salt-pan basins. 9 p.

Professional Paper 400-B, p. B77-B79: Pierce, A. P., 1960, Studies of helium and associated gases.

## Mineralogy

*Circular 74: Frondel, J. W. and Fleischer, Michael, 1950, A glossary of uranium- and thorium-bearing minerals. 20 p. (superseded by Circular 194)

*Circular 194: Frondel, J. W. and Fleischer, Michael, 1952, A glossary of uranium- and thorium-bearing minerals, second edition. 25 p. (superseded by Bulletin 1009-F).

Bulletin 1009-F: Frondel, J. W. and Fleischer, Michael, 1955, Glossary of uranium- and thorium-bearing minerals. 41 p.

Bulletin 1036-G: Frondel, Clifford, Riska, Daphne, and Frondel, J. W., 1956, X-ray powder data for uranium and thorium minerals. 63 p.

Bulletin 1064: Frondel, Clifford, 1958, Systematic mineralogy of uranium and thorium. 400 p., 1 pl., 24 figs.

## Geophysics

Professional Paper 300, p. 715-719: Sakakura, A. Y., 1956, Air scattering of gamma rays from thick uranium sources.

Bulletin 1052-A: Sakakura, A. Y., 1957, Scattered gamma rays from thick uranium sources. 50 p., 21 figs.

Bulletin 1052-C: Barnes, D. F., 1958, Infrared luminescence of minerals. 87 p., 2 pls., 2 figs.

Bulletin 1052-E: Rogers, A. S., 1958, Physical behavior and geologic control of radon in mountain streams. 25 p., 3 pls., 10 figs.

Bulletin 1052-F: Vaughn, W. W., Rhoden, V. C., Wilson, E. E., and Faul, Henry, 1959, Scintillation counters for geologic use. 28 p., 3 pls., 12 figs.

Bulletin 1052-G: Bunker, C. M. and Hamontre, H. C. (USBM), 1959, A comparison among caliper-log, gamma-ray-log, and other diamond drill-hole data. 15 p., 2 figs.

Bulletin 1052-H: Keller, G. V. and Licastro, P. H., 1959, Dielectric constants and electrical resistivity of natural-state cores. 29 p., 21 figs.

Bulletin 1052-I: Sakakura, A. Y., 1959, Equation of continuity in geology with applications to the transport of radioactive gas. 19 p., 6 figs.

Bulletin 1084-A: Rosholt, J. N., Jr., 1959, Natural radioactive disequilibrium of the uranium series. 30 p., 4 figs.

Professional Paper 400-B, p. B111-B114: Tanner, A. B., 1960, Usefulness of the emanation method in geologic exploration.

_____, p. B119-B121: Gillou, R. B. and Schmidt, R. G., 1960, Correlation of aeroradioactivity data with areal geology.

## Geochronology

*Circular 271: Stieff, L. R., Stern, T. W., and Milkey, R. G., 1953, A preliminary determination of the age of some uranium ores of the Colorado Plateau by the lead-uranium method. 19 p., 7 figs.

Professional Paper 300, p. 549-555: Stieff, L. R. and Stern, T. W., 1956, Interpretation of the discordant age sequence of uranium ores.

Bulletin 1070-B: Larsen, E. S., Jr., Gottfried, David, Jaffe, H. W., and Waring, C. L., 1958, Lead-alpha ages of the Mesozoic batholiths of Western North America. 28 p., 2 figs.

Bulletin 1097-A: Gottfried, David, Jaffe, H. W., and Senftle, F. E., 1959, Evaluation of the lead-alpha (Larsen) method for determining ages of igneous rocks. 63 p., 1 pl., 6 figs.

Bulletin 1097-B: Jaffe, H. W., Gottfried, David, Waring, C. L., and Worthing, H. W., 1959, Lead-alpha age determinations of accessory minerals in igneous rocks (1953-57). 84 p.

Professional Paper 334-A: Stieff, L. R., Stern, T. W., Oshiro, Saiki, and Senftle, F. E., 1959, Tables for the calculation of lead isotope ages. 40 p., 2 figs.

Professional Paper 400-B, p. B45-B48: Stern, T. W., Stieff, L. R., Klemic, Harry, and Delevaux, M. H., 1960, Lead isotope age studies in Carbon County, Pennsylvania.

## Tectonics

Professional Paper 300, p. 329-335: Osterwald, F. W., 1956, Relation of tectonic elements in Precambrian rocks to uranium deposits in the Cordilleran foreland of the Western United States.

Map MF-120: Finnell, T. L. and Parrish, I. S., 1958, Uranium deposits and principal ore-bearing formations in the central Cordilleran foreland region. Scale 1:750,000.

Map MF-125: Osterwald, F. W. and Dean, B. G., 1957, Preliminary tectonic map of North Dakota showing the distribution of uranium deposits. Scale 1:500,000.

Map MF-126: _____, 1958, Preliminary tectonic map of western Montana showing the distribution of uranium deposits. Scale 1:500,000.

Map MF-127: _____, 1958, Preliminary tectonic map of Wyoming east of the overthrust belt, showing the distribution of uranium deposits. Scale 1:500,000.

Map MF-128: _____, 1957, Preliminary tectonic map of western South Dakota, showing the distribution of uranium deposits. Scale 1:500,000.

Map MF-129: _____, 1958, Preliminary tectonic map of western Nebraska and northwestern Kansas showing the distribution of uranium deposits. Scale 1:500,000.

Map MF-130: _____, 1958, Preliminary tectonic map of northern Colorado and northeastern Utah, showing the distribution of uranium deposits. Scale 1:500,000.

## Analytical methods

One of the Survey's more important contributions to the Nation's uranium program has been the development of rapid, precise, and accurate methods of analysis for uranium, thorium, and other elements important to the investigations. Survey publications on analytical techniques and procedures are listed below.

*Circular 135: Jaffe, E. B., 1951, Abstracts of the literature on the synthesis of apatites and some related phosphates. 78 p.

*Circular 199: Grimaldi, F. S., May, Irving, and Fletcher, M. H., 1952, U. S. Geological Survey fluorimetric methods of uranium analysis. 20 p., 16 figs.

Circular 311: Fletcher, M. H. and Warner, E. R., 1953, A fluorimeter for solutions. 9 p., 8 figs.

Bulletin 992: Brannock, W. W. and others, 1953, Contributions to geochemistry. 94 p., 14 pls., 17 figs. Contains:

Pt. 2: Cuttitta, Frank, A photometric method for the estimation of the oil yield of oil shale.

Pt. 3: _____, A volumetric method for the estimation of the oil yield of oil shale.

Pt. 4: Grimaldi, F. S. and Levine, Harry, The fluorimetric determination of aluminum in phosphate rock with 8-hydroxiquinoline.

Pt. 5: Grimaldi, F. S., The determination of phosphorus in rocks containing vanadium.

Bulletin 1006: Grimaldi, F. S., May, Irving, Fletcher, M. H., and Titcomb, Jane, 1954, Collected papers on methods of analysis for uranium and thorium. 184 p., 8 pls., 25 figs. Contains:

Pt. 1: Grimaldi, F. S., May, Irving, Fletcher, M. H., and Titcomb, Jane, Summary of methods for the determination of uranium and thorium.

Pt. 2: Foster, M. D., Stevens, R. E., Grimaldi, F. S., Schlecht, W. G., and Fleischer, Michael, Methods for the complete decomposition of rock and ore samples to be analyzed for very small amounts of uranium and thorium.

Pt. 3: Grimaldi, F. S., The Geological Survey cupferron precipitation-extraction method for the determination of very small amounts of uranium in naturally occurring minerals.

Pt. 4: Foster, M. D. and Stevens, R. E., The Geological Survey carbonate-phosphate-peroxide method for the determination of very small amounts of uranium in naturally occurring minerals.

Pt. 5: Grimaldi, F. S., Elimination of interference by nickel in the determination of uranium by means of zinc amalgam reductors.

Pt. 6: Grimaldi, F. S. and Levine, Harry, The visual fluorimetric determination of uranium in low-grade ores.

Pt. 7: Grimaldi, F. S., A volumetric filtering pipette.

Pt. 8: Fletcher, M. H., A study of critical factors in the "direct" fluorimetric determination of uranium.

Pt. 9: Grimaldi, F. S., Ward, F. N., and Fuyat, R. K., A direct fluorimetric method for the determination of small amounts of uranium in the field and laboratory.

Pt. 10: Fletcher, M. H. and May, Irving, An improved fluorimeter for the determination of uranium in fluoride melts.

Pt. 11: Fletcher, M. H., May, Irving, and Slavin, Morris, A transmission fluorimeter for use in the fluorimetric method of analysis for uranium.

Pt. 12: Fletcher, M. H., May, Irving, and Anderson, J. W., The design of the Model V transmission fluorimeter.

Pt. 13: May, Irving, and Fletcher, M. H., A battery-powered fluorimeter for the determination of uranium.

Pt. 14: Grimaldi, F. S. and Guttag, N. S., Short routine direct method for the fluorimetric determination of uranium in phosphate rocks.

Pt. 15: Guttag, N. S. and Grimaldi, F. S., Fluorimetric determination of uranium in shales, lignites and monazites after alkali carbonate separation.

Pt. 16: Rowe, J. J., Noninterference of arsenate ion in the volumetric determination of uranium using the Jones reductor.

Pt. 17: Smith, A. P. and Grimaldi, F. S., The fluorimetric determination of uranium in saline and nonsaline waters.

Pt. 18: Grimaldi, F. S. and Fairchild, J. G., The Geological Survey phosphate-fluoride-iodate method for the determination of very small amounts of thorium in naturally occurring materials.

Pt. 19: Fahey, J. J. and Foster, M. D., The Geological Survey carbonate-iodate-iodine method for the determination of small amounts of thorium in naturally occurring materials.

Pt. 20: Grimaldi, F. S. and Warshaw, C. M., The determination of thorium in high-grade and low-grade ores.

Pt. 21: Levine, Harry and Grimaldi, F. S., Mesityl oxide extraction method for thorium analysis.

Professional Paper 300, p. 605-617: Grimaldi, F. S., 1956, The analytical chemistry of uranium and thorium.

Bulletin 1036-E: Waring, C. L., Franck, Mona, and Sherwood, A. M., 1956, An application of spectrographic microphotometric scanning. 12 p.

Bulletin 1036-F: Waring, C. L. and Worthing, H. W., 1956, A spectrographic method for determining the hafnium-zirconium ratio in zircon. 10 p., 3 figs.

Bulletin 1036-M: Parshall, E. E. and Rader, L. F., Jr., 1957, Model '54 transmission and reflection fluorimeter for determination of uranium with adaptation for field use. 31 p., 1 pl., 13 figs.

Bulletin 1036-N: Carron, M. K., Naeser, C. R., Rose, H. J., Jr., and Hildebrand, F. A., 1958, Fractional precipitation of rare earths with phosphoric acid. 23 p., 2 figs.

Circular 427: Vaughn, W. W., Wilson, E. E., and Ohm, J. M., 1960, A field instrument for quantitative determination of beryllium by activation analysis. 10 p., 8 figs.

Professional Paper 400B, p. B39-B41: Myers, A. T., Hamilton, J. C., and Wilmarth, V. R., 1960, A study of rhenium and molybdenum in uranium ore from the Runge mine, Fall River County, South Dakota, by means of a spectrographic and concentration method.

_____, p. B443-B446: Evans, H. T., Jr., 1960, Recent developments in the crystal chemistry of vanadium oxide minerals.

_____, p. B485-B486: Cuttitta, Frank and Warr, J. J., 1960, Determination of lead in pyrites.

_____, p. B483-B484: Warr, J. J. and Cuttitta, Frank, 1960, The determination of lead in iron-bearing materials.

_____, p. B486-B487: Cuttitta, Frank and Warr, J. J., 1960, Determination of lead in zircon with dithizone.

_____, p. B487-B488: _____, 1960, Preparation of lead iodide for mass spectroscopy.

_____, p. B488-B490: Cuttitta, Frank, 1960, Determination of small quantities of oxygen adsorbed on anatase.

_____, p. B491-B493: Cuttitta, Frank, Senftle, F. E., and Walker, E. C., 1960, Preliminary tests of isotopic fractionation of copper adsorbed on quartz and sphalerite

_____, p. B504-B506: Hoyte, A. F., 1960, A gamma-ray adsorption method for the determination of uranium in ores.

_____, p. B507-B508: Martinez, Prudencio, 1956, Method of grinding cesium iodide crystals.

## RECONNAISSANCE FOR URANIUM AND THORIUM

The Geological Survey began a reconnaissance search for strategic minerals in the late 1930's. In 1944 the investigations were largely reoriented toward the so-called "trace elements", particularly uranium and thorium, and some support was received from the Manhattan Engineer District. Ground reconnaissance in the conterminous United States and Alaska, on behalf of the Atomic Energy Commission, began in 1947 and continued until 1955. Ground reconnaissance was augmented by airborne radioactivity reconnaissance that began on a small scale in 1948; this phase of the program continued until 1956.

One of the most useful products of the reconnaissance program, from a long-range standpoint, has been the development and refinement of scientific methods of prospecting for fissionable and other elements.

### Prospecting methods

Prospecting for uranium and thorium poses some unusual problems, not the least of which is that many uranium- and thorium-bearing minerals cannot be identified visually, but must be located by measurements of their radioactivity. Accordingly early investigations depended largely on Geiger counters, either hand-carried, carborne, or airborne. In recent years considerable progress has been made in the development of geochemical, mineralogical, hydrogeological, and other methods of finding both uranium ore and environments favorable for the concentration of ore.

Survey publications on methods of prospecting for uranium and thorium are:

*Circular 127: Hartsock, Lydia, and Pierce, A. P., 1952, Geochemical and mineralogical methods of prospecting for mineral deposits, by A. Ye Fersman and others, translated from the Russian. 37 p.

Bulletin 988-I: Nelson, J. M., 1953, Prospecting for uranium with car-mounted equipment. 11 p., 4 figs.

Professional Paper 300, p. 621-625: Foote, R. S. (AEC) and Page, L. R., 1956, Techniques for prospecting for uranium and thorium.

_____, p. 627-631: Page, L. R., 1956, Geologic prospecting for uranium and thorium.

_____, p. 647-650: Overstreet, W. C., Theobald, P. K., Whitlow, J. W., and Stone, Jerome, 1956, Heavy-mineral prospecting.

_____, p. 559-665: Lovering, T. S., Lakin, H. W., Ward, F. N., and Ganney, F. C., 1956, The use of geochemical techniques and methods of prospecting for uranium.

_____, p. 667-671: Fix, P. F., 1956, Hydrogeochemical prospecting for uranium.

_____, p. 673-680: Denson, N. M., Zeller, H. D., and Stephens, J. G., 1956, Water sampling as a guide to the search for uranium deposits and its use in evaluating widespread volcanic units as potential source beds for uranium.

_____, p. 705-713: Stead, F. W., 1956, Instruments and techniques for measuring radioactivity in the field.

Bulletin 1030-E: Chew, R. T., 3rd., 1956, Study of radioactivity in modern stream gravels as a method of prospecting. 21 p. 1 pl., 9 figs.

Bulletin 1036-J: Ward, F. N. and Marranzino. A. P., 1957, Field determination of uranium in natural waters. 12 p., 1 fig.

Bulletin 1036-L: Thompson, C. E. and Lakin, H. W., 1957, A field chromatographic method for determination of uranium in soils and rocks. 12 p., 2 figs.

Bulletin 1071: Theobald, P. K., Jr., 1957, The gold pan as a quantitative geologic tool. 54 p., 4 figs.

## Reconnaissance investigations

As much of the data obtained during the Survey's reconnaissance for uranium and thorium was of ephemeral interest, only the more important investigations and deposits have been reported upon in formal Survey publications. A very large number of such reports, however, were transmitted to the AEC as Trace Elements Reports, and each of the Semiannual Reports contains a summary of reconnaissance activities during the period covered.

### Conterminous United States

Circular 219: Gott, G. B. and Erickson, R. L., 1952, Reconnaissance for uranium and copper deposits in parts of New Mexico, Colorado, Utah, Idaho, and Wyoming. 16 p., 1 fig.

Circular 313: Moore, G. W., and Stephens, J. G., 1954, Reconnaissance for uranium-bearing carbonaceous rocks in California and adjacent parts of Oregon and Nevada. 8 p., 2 figs.

Bulletin 1046-N: Lovering, T. G. and Beroni, E. P., 1959, Preliminary study of radioactive limonite in California, Utah, and Wyoming. 46 p., 1 pl., 14 figs.

Bulletin 1074-B: Weis, P. L., Armstrong, F. C., and Rosenblum, Samuel, 1958, Reconnaissance for radioactive minerals in Washington, Idaho, and eastern Montana, 1952-55. 42 p., 1 pl., 2 figs.

Bulletin 1087-G: Landis, E. R., 1960, Uranium content of ground and surface waters in a part of the central Great Plains. 36 p., 1 pl., 1 fig.

### Arizona

Map GP-120: Meuschke, J. L., 1955, Airborne radioactivity survey of the Painted Desert area, Coconino and Navajo Counties, Arizona. Scale approx. 1:63,360.

Map GP-124: _____, 1955, Airborne radioactivity survey of the Pinto Chinle area, Apache County, Arizona. Scale approx. 1:63,360.

Colorado

Circular 236: Burbank, W. S. and Pierson, C. T., 1953, Preliminary results of radiometric reconnaissance of parts of the northwestern San Juan Mountains, Colorado. 11 p., 2 figs.

Circular 294: Pierson, C. T. and Singewald, Q. D., 1953, Results of reconnaissance for radioactive minerals in parts of the Alma district, Park County, Colorado. 9 p., 1 pl., 2 figs.

Map GP-126: Johnson, R. W., 1955, Airborne reconnaissance of part of Moffat County, Colorado, south of 40°45'. Scale approx. 1:63,360.

Bulletin 1046-O: Pierson, C. T., Weeks, W. F., and Kleinhampl, F. J., 1958, Reconnaissance for radioactivity in the metal-mining districts of the San Juan Mountains, Colorado. 29 p., 2 pls., 3 figs.

Bulletin 1087-A: Wilmarth, V. R., 1959, Geology of the Garo uranium-vanadium-copper deposit, Park County, Colorado. 21 p., 5 pls., 2 figs.

Idaho

Bulletin 1046-C: Armstrong, F. C. and Weis, P. L., 1957, Uranium-bearing minerals in placer deposits of the Red River Valley, Idaho County, Idaho. 12 p., 1 pl., 1 fig.

Nevada

Bulletin 1009-C: Lovering, T. G., 1954, Radioactive deposits of Nevada. 44 p., 7 figs.

New Mexico

Circular 354: Griggs, R. L., 1954, A reconnaissance for uranium in New Mexico, 1953. 9 p., 3 figs.

Bulletin 1009-L: Lovering, T. G., 1956, Radioactive deposits of New Mexico. 76 p., 7 pls., 9 figs.

South Dakota

Circular 286: Vickers, R. C., 1953, An occurrence of autunite, Lawrence County, South Dakota. 5 p., 2 figs.

Circular 351: _____, 1954, Occurrences of radioactive minerals in the Bald Mountain gold-mining area, northern Black Hills, South Dakota. 8 p., 2 figs.

Utah

Circular 312: Wilmarth, V. R., 1953, Yellow Canary uranium deposits, Daggett County, Utah. 8 p., 2 figs.

Circular 322: Wyant, D. G., 1954, The East Slope no. 2 uranium deposit, Piute County, Utah. 6 p., 1 pl., 2 figs.

Circular 239: Beroni, E. P., McKeown, F. A., Stugard, Frederick, Jr., and Gott, G. B., 1953, Uranium deposits of the Bulloch group of claims, Kane County, Utah. 9 p., 3 pls., 3 figs.

Circular 349: Zeller, H. D., 1955, Reconnaissance for uranium-bearing carbonaceous materials in southern Utah. 9 p., 4 figs.

Map GP-127: Johnson, R. W., 1955, Airborne radioactivity survey of the Myton area, Duchesne and Uintah Counties, Utah. Scale approx. 1:63,360.

Wisconsin

Bulletin 1042-B: Vickers, R. C., 1956, Airborne and ground reconnaissance of part of the syenite complex near Wausau, Wisconsin. 20 p., 5 figs.

Wyoming

Bulletin 1046-M: Stephens, J. G. and Bergin, M. G., 1959, Reconnaissance investigations of uranium occurrences in the Saratoga area, Carbon County, Wyoming. 19 p., 4 pls., 5 figs.

## Alaska

Reconnaissance for radioactive materials in Alaska began in 1945 as an outgrowth of earlier searches for strategic minerals, and continued until the close of the Raw Materials sponsored program in 1958. The reconnaissance discovered a number of occurrences of radioactive minerals and one deposit, on Prince of Wales Island, that is now (1960) being mined.

Results of many of the reconnaissance studies in Alaska were published in the Circular series in 1952, 1953, and 1954. More comprehensive reports have been published in later years as Bulletins or Maps.

Publications covering the Survey's reconnaissance for radioactive minerals in Alaska are:

*Circular 184: Moxham, R. M. and Nelson, A. E., 1952, Reconnaissance for radioactive materials in south-central Alaska. 36 p., 1 pl., 4 figs.

Circular 185: White, M. G., 1952, Reconnaissance for radioactive deposits along the upper Porcupine and lower Coleen Rivers, northeastern Alaska. 13 p., 3 figs.

Circular 195: _____, 1952, Radioactivity of selected rocks and placer concentrates from northeastern Alaska. 12 p., 5 figs.

Circular 196: White, M. G., West, W. S., Tolbert, G. E., Nelson, A. E., and Houston, J. R., 1952, Preliminary report of reconnaissance for uranium in Alaska, 1951. 17 p., 4 figs.

Circular 207: Moxham, R. M. and Nelson, A. E., 1952, Reconnaissance for radioactive deposits in the southern Cook Inlet region, Alaska, 1949. 7 p., 1 pl., 1 fig.

Circular 214: West, W. S. and White, M. G., 1952, The occurrence of zeunerite at Brooks Mountain, Seward Peninsula, Alaska. 7 p., 1 pl., 1 fig.

Circular 244: White, M. G., West, W. S., and Matzko, J. J., 1953, Reconnaissance for radioactive deposits in the vicinity of Teller and Cape Nome, Seward Peninsula, Alaska, 1946-47. 8 p., 2 pls.

Circular 248: Wedow, Helmuth, Jr. and others, 1953, Preliminary summary of reconnaissance for uranium and thorium in Alaska, 1952. 15 p., 1 pl., 1 fig.

Circular 250: Gault, H. R., Killeen, P. L., West, W. S. and others, 1953, Reconnaissance for radioactive deposits in the northeastern part of the Seward Peninsula, Alaska, 1945-47 and 1951. 31 p., 3 pls., 4 figs.

Circular 255: White, M. G. and Killeen, P. L., 1953, Reconnaissance for radioactive deposits in the lower Yukon-Kuskokwim highlands region, Alaska. 18 p., 4 figs.

Circular 265: Moxham, R. M. and West, W. S., 1953, Radioactivity investigations in the Serpentine-Kougarok area, Seward Peninsula, Alaska. 11 p., 2 figs.

Circular 279: White, M. G. and Stephens, J. M., 1953, Reconnaissance for radioactive deposits in the Ruby-Poorman and Nixon Fork districts, west-central Alaska. 19 p., 4 figs.

Circular 300: West, W. S., 1953, Reconnaissance for radioactive deposits in the Derby Mountains, Seward Peninsula, 1948. 7 p., 1 pl.

Circular 316: Wedow, Helmuth, Jr., 1954, Reconnaissance for radioactive deposits in the Eagle-Nation area, east-central Alaska, 1948. 9 p., 1 pl., 1 fig.

Circular 317: Moxham, R. M., 1954, Reconnaissance for radioactive deposits in the Manley Hot Springs - Rampart district, east-central Alaska, 1948. 6 p., 2 figs.

*Circular 319: White, M. G. and West, W. S., 1953, Reconnaissance for uranium in the Lost River area, Seward Peninsula, Alaska, 1951. 4 p., 1 fig.

Circular 328: West, W. S., 1954, Reconnaissance for radioactive deposits in the lower Yukon-Kuskokwim region, Alaska, 1952. 10 p., 2 pls., 2 figs.

Circular 331: Wedow, Helmuth, Jr. and others, 1954, Reconnaissance for radioactive deposits in eastern interior Alaska, 1946. 36 p., 11 figs.

Circular 335: Wedow, Helmuth, Jr., White, M. G., and others, 1954, Reconnaissance for radioactive materials in east-central Alaska, 1949. 22 p., 2 pls., 6 figs.

Circular 348: Nelson, A. E., West, W. S., and Matzko, J. J., 1954, Reconnaissance for radioactive materials in eastern Alaska, 1952. 21 p., 6 figs.

Bulletin 1024-A: Robinson, G. D., Wedow, Helmuth, Jr., and Lyons, J. B., 1955, Radioactivity investigations in the Cache Creek area, Yentna district, Alaska, 1945. 23 p., 6 pls., 4 figs.

Bulletin 1024-B: West, W. S. and Benson, P. D., 1955, Investigations for radioactive deposits in southeastern Alaska. 33 p., 3 pls., 1 fig.

Bulletin 1024-C: Killeen, P. L. and Ordway, R. J., 1955, Radioactivity investigations at Ear Mountain, Seward Peninsula, Alaska, 1945. 36 p., 2 pls., 1 fig.

Bulletin 1058-A: Houston, J. R., Bates, R. G., Velikanje, R. S. and Wedow, Helmuth, Jr., 1958, Reconnaissance for radioactive deposits in southeastern Alaska, 1952. 31 p., 3 pls., 4 figs.

Bulletin 1058-H: Sainsbury, E. T., in press, Geology of part of Prince of Wales Island.

Photogeologic maps

Three photogeologic maps of areas on Prince of Wales Island have been published at a scale of 1:24,000. They are:

Map I-230: Pillmore, C. L. and McQueen, Kathleen, 1956, Salt Chuck area, Prince of Wales Island, Alaska, showing linear features as seen on aerial photographs.

Map I-231: _____, 1956, Hollis area, Prince of Wales Island, Alaska, showing linear features as seen on aerial photographs, Part 1.

Map I-232: _____, 1956, Hollis area, Prince of Wales Island, Alaska, showing linear features as seen on aerial photographs, Part 2.

## URANIUM IN SANDSTONE-TYPE DEPOSITS

### Colorado Plateau region

In the Colorado Plateau region the Survey's first geologic investigations on behalf of the Division of Raw Materials began in 1947; these were studies of specific areas prerequisite to an exploratory drilling program. As the program developed, increasing attention was devoted to longer-range scientific studies of the entire region as well as to detailed geologic investigations of important areas within the region. The investigations included geologic quadrangle mapping, photogeologic mapping, stratigraphic studies, geobotanical studies, regional and district geophysical studies, and investigations of the mineralogy and geochemistry of the Plateau ores. Survey reports stemming from the Colorado Plateau program published through November 30, 1960 are listed below.

#### General publications

Bulletin 936-P: Fischer, R. P., 1942, Vanadium deposits of Colorado and Utah, a preliminary report. 63 p., 2 pls.

Preliminary Map 3-226: _____, 1944, Vanadium region of southwestern Colorado and southeastern Utah. Scale 1 inch = nearly 3 miles.

Bulletin 988-B: Weir, D. B., 1952, Geologic guides to prospecting for carnotite ores on the Colorado Plateau. 13 p., 9 figs.

Map MF-16: Finch, W. I., 1955, Preliminary geologic map showing the distribution of uranium deposits and the principal ore-bearing formations of the Colorado Plateau. Scale 1:500,000.

Bulletin 1009-J: McKay, E. J., 1955, Criteria for outlining areas favorable for uranium deposits in parts of Colorado and Utah. 18 p., 2 pls., 1 fig.

Professional Paper 279: Hunt, C. B., 1956, Cenozoic history of the Colorado Plateau. 99 p., 62 figs.

Professional Paper 300, p. 143-154: Fischer, R. P., 1956, Uranium-vanadium-copper deposits on the Colorado Plateau.

Map MF-54: Chew, R. T., 3rd, 1956, Uranium and vanadium deposits of the Colorado Plateau that produced more than 1,000 tons through June 30, 1955. Scale 1:750,000

Bulletin 1030-D: Buah, A. L. and Stager, H. K., 1956, Accuracy of ore-reserve estimates for uranium-vanadium deposits on the Colorado Plateau. 18 p., 1 pl., 5 figs.

Stratigraphic studies

The first stratigraphic studies on the Colorado Plateau were limited to the Morrison formation, from which most of the early production of uranium ore was taken. Later the investigations were extended to include most of the sedimentary formations in the region. Survey publications stemming from the stratigraphic studies are:

Bulletin 1009-E: Craig, L. C. and others, 1955, Stratigraphy of the Morrison and related formations, Colorado Plateau region, a preliminary report. 44 p., 13 figs.

Professional Paper 300, p. 155-170: Shoemaker, E. M., Structural features of the central Colorado Plateau and their relation to uranium deposition.

_____, p. 207-211: Jobin, D. A., 1956, Regional transmissivity of the exposed sediments of the Colorado Plateau as related to the distribution of uranium deposits.

_____, p. 227-231: Poole, F. G. and Williams, G. A., 1956, Direction of sediment transport in the Triassic and associated formations of the Colorado Plateau.

_____, p. 239-241: Shawe, D. R., 1956, Significance of roll ore bodies in genesis of uranium-vanadium deposits on the Colorado Plateau.

Bulletin 1046-Q: Stewart, J. H., Williams, G. A., Albee, H. F., and Raup, O. B., 1959, Stratigraphy of Triassic and associated formations in part of the Colorado Plateau region, with a section on "Sedimentary petrology" by R. A. Cadigan. 80 p., 1 pl., 15 figs.

Bulletin 1074-D: Finch, W. I., 1959, Geology of uranium deposits in Triassic rocks of the Colorado Plateau region. 40 p., 5 pls., 2 figs.

## Geobotanical investigations

The use of certain plants as guides to carnotite deposits has been studied by the Survey since 1949, and such investigations of vegetation have proved useful in the search for uranium deposits in various parts of the Colorado Plateau and elsewhere. The Survey's geobotanical studies are reported in the following publications:

Professional Paper 300, p. 681-686: Cannon, H. L. and Kleinhampl, F. J., 1956, Botanical methods of prospecting for uranium.

Bulletin 1009-M: Cannon, H. L. and Starrett, W. H., 1956, Botanical prospecting for uranium on La Ventana Mesa, Sandoval County, New Mexico. 17 p., 6 figs.

Bulletin 1030-M: Cannon, H. L., 1957, Description of indicator plants and methods of prospecting for uranium deposits on the Colorado Plateau. 18 p., 102 figs.

Bulletin 1085-A: _____, 1960, The development of botanical methods of prospecting for uranium on the Colorado Plateau. 50 p., 7 pls., 1 fig.

Professional Paper 400-B, p. B96-B97: _____, 1960, Geochemistry of sandstones and related vegetation in the Yellow Cat area of the Thompson district, Grand County, Utah.

## Geophysical investigations

Electrical resistivity surveys directed toward outlining areas favorable for uranium deposits were made by the Survey in the Colorado Plateau in 1950, and in later years other geophysical techniques were employed for the same purpose. Survey publications on geophysical investigations on the Plateau, which are still in progress (1960), are:

Professional Paper 300, p. 721-726: Black, R. A., 1956, Geophysical exploration for uranium on the Colorado Plateau.

Bulletin 1052-J: Keller, G. V., 1959, Electrical properties of sandstones of the Morrison formations. 38 p., 2 pls., 14 figs.

Bulletin 1083-B: Keller, G. V., 1959, Directional resistivity measurements in exploration for uranium on the Colorado Plateau. 36 p., 20 figs.

Mineralogical and geochemical investigations

Prior to 1947 little was known of the mineralogy and geochemistry of uranium minerals and ores. These subjects have been investigated intensively by the Survey, and are reported upon in a number of publications:

Circular 224: Waters, A. C. and Granger, H. C., 1953, Volcanic debris in uraniferous sandstones, and its possible bearing on the origin and precipitation of uranium. 26 p., 12 figs.

Bulletin 1009-B: Weeks, A. D. and Thompson, M. E., 1954, Identification and occurrence of uranium and vanadium minerals on the Colorado Plateau. 50 p.

Bulletin 1074-A: Botinelly, Theodore, and Weeks, A. D., 1957, Mineralogic classification of uranium-vanadium deposits of the Colorado Plateau. 5 p., 1 pl.

Professional Paper 300, p. 187-193: Weeks, A. D., Mineralogy and oxidation of the Colorado Plateau uranium ores.

Professional Paper 320: Garrels, R. M. and Larsen, E. S., 3rd, comp., 1959, Geochemistry and mineralogy of the Colorado Plateau uranium ores. 236 p., 8 pls., 12 figs.

Bulletin 1112-B: Miesch, A. T., Shoemaker, E. M., Newman, W. L., and Finch, W. I., 1960, Chemical composition as a guide to the size of sandstone-type uranium deposits in the Morrison formation of the Colorado Plateau. 45 p., 12 figs.

Professional Paper 400-B, p. B42-B44: Fischer, R. P. and Stewart, J. H., 1960, Distribution and lithologic characteristics of sandstone beds that contain deposits of copper, vanadium, and uranium.

_____, p. B421-B422: Rosholt, J. N., Jr., 1960, A study of uranium migration in sandstone-type deposits.

Studies of photogeologic mapping techniques

In addition to 18 maps of 7½-minute quadrangles in the Geologic Quadrangle (GQ) Map series and 89 preliminary geologic maps in the Field Studies (MF) Map series stemming from its Colorado Plateau investigations, the Survey has published 216 photogeologic maps in the Miscellaneous Investigations (I) series. These maps were prepared from aerial photographs of areas in Utah and Arizona for which little or no topographic coverage was available. Because of the conditions under which they were prepared, the maps vary considerably in the amount of detail shown, but they served a most useful purpose as guides to prospecting and as bases for geologic studies during the early years of the Colorado Plateau investigations; many of them are still of value as preliminary geologic maps.

An outstanding achievement of the photogeologic mapping program from the long-range standpoint has been the development of vastly improved techniques and procedures for interpreting geology from aerial photographs. Survey publications on photogeologic methods are:

Bulletin 1043-A: Ray, R. G., 1955, Photogeologic procedures in geologic interpretation and mapping. 21 p., 12 figs.

Bulletin 1043-B: Pillmore, C. L., 1957, Applications of high-order stereoscopic plotting instruments to photogeologic studies. 2 p.

Bulletin 1043-C: Hemphill, W. R., 1958, Determination of quantitative geologic data with stereometer-type instruments. 22 p., 2 pls., 5 figs.

Professional Paper 400-B, p. B136-B138: Fischer, W. A., 1960, Spectral reflectance measurements as a basis for film-filter selection for photographic differentiation of rock units.

Professional Paper 373: Ray, R. G., in press, Aerial photographs in geologic interpretation and mapping.

## Publications on areas within the Colorado Plateau

### Rifle Creek area, Colorado

The Rifle Creek area is in Garfield County, Colorado, near the town of Rifle, near the northeastern edge of the Plateau. One report on the area is in press:

Bulletin 1101: Fischer, R. P., in press, Uranium-vanadium deposits of the Rifle Creek area, Colorado.

### Mesa, Montrose, and San Miguel Counties, Colorado

The Survey's first uranium investigations on the Colorado Plateau were in the western parts of Mesa, Montrose, and San Miguel Counties, Colorado, and extending westward into Grand County, Utah and southward into Dolores County, Colorado. This area includes an arcuate band of vanadium-uranium mineralization that has been named the "Uravan Mineral Belt" by R. P. Fischer and L. S. Hilpert of the Survey.

Geologic maps: The first Survey publication on the area was:

Preliminary Map 3-173: Stokes, W. L., Russell, R. T., Fischer, R. P., and Butler, A. P., Jr., 1945, Geologic map of the Gateway area, Mesa County, Colorado and adjoining part of Grand County, Utah. Scale 1:62,360.

In later years 18 maps of 7½-minute quadrangles in the area have been published in the GQ series. Of these quadrangles, 16 previously had been covered by Field Studies maps in the MF series. In the listing

of the GQ maps below the number of the MF map covering the quadrangle is given in parentheses following the citation to the GQ map. All of the maps of this area in both the GQ and MF series are published at a scale of 1:24,000.

Map GQ-33: Cater, F. W., Jr., 1954, Geology of the Bull Canyon quadrangle, Colorado.

Map GQ-55: _____, 1955, Geology of the Gateway quadrangle, Colorado.

Map GQ-57: McKay, E. J., 1955, Geology of the Atkinson Creek quadrangle, Colorado. (also Map MF-18).

Map GQ-58: _____, 1955, Geology of the Red Canyon quadrangle, with a section on "The Mines" by D. A. Jobin. (also Map MF-17).

Map GQ-59: Cater, F. W., Jr., 1955, Geology of the Gypsum Gap quadrangle, Colorado. (also Map MF-19).

Map GQ-60: _____, 1955, Geology of the Pine Mountain quadrangle, Colorado. (also Map MF-20).

Map GQ-61: _____, 1955, Geology of the Calamity Mesa quadrangle, Colorado, with a section on "The Mines" by H. K. Stager. (also Map MF-32).

Map GQ-64: _____, 1955, Geology of the Horse Range Mesa quadrangle, Colorado, with a section on "The Mines" by A. L. Bush and Henry Bell, 3rd. (also Map MF-29).

Map GQ-65: _____, 1955, Geology of the Naturita NW quadrangle, Colorado, with a section on "The Mines" by J. D. Vogel. (also Map MF-30).

Map GQ-66: _____, 1955, Geology of the Joe Davis Hill quadrangle, Colorado, with a section on "The Mines" by Henry Bell, 3rd. (also Map MF-27).

Map GQ-68: _____, 1955, Geology of the Egnar quadrangle, Colorado, with a section on "The Mines" by A. L. Bush and Henry Bell, 3rd. (also Map MF-26).

Map GQ-69: _____, 1955, Geology of the Hamm Canyon quadrangle, Colorado. (also Map MF-21).

Map GQ-71: _____, 1955, Geology of the Davis Mesa quadrangle, Colorado. (also Map MF-31).

Map GQ-72: Withington, C. F., 1955, Geology of the Paradox quadrangle, Colorado. (also Map MF-22).

Map GQ-77: Cater, F. W., Jr., 1955, Geology of the Anderson Mesa quadrangle, Colorado, with a section on "The Mines" by C. F. Withington. (also Map MF-25).

Map GQ-78: Cater, F. W., Jr., Butler, A. P., Jr., and McKay, E. J., 1955, Geology of the Uravan quadrangle, Colorado, with a section on "The Mines" by R. L. Boardman. (also Map MF-24).

Map GQ-81: Shoemaker, E. M., 1955, Geology of the Juanita Arch quadrangle, Colorado. (also Map MF-28).

Map GQ-83: _____, Geology of the Roc Creek quadrangle, Colorado. (also Map MF-23).

Book reports and maps other than quadrangle maps that have been published on the area are:

Bulletin 988-A: Fischer, R. P. and Hilpert, L. S., 1952, Geology of the Uravan Mineral Belt. 12 p., 3 pls., 5 figs.

Professional Paper 300, p. 213-219: Phoenix, D. A., 1956, Relation of carnotite deposits to permeable rocks in the Morrison formation, Mesa County, Colorado.

_____, p. 221-226: Boardman, R. L., Ekren, E. B., and Bowers, H. E., 1956, Sedimentary features of upper sandstone lenses in the Uravan district, Colorado.

Map MF-122: Eicher, L. J., Hedlund, D. C., and Miller, G. A., 1957, Preliminary geologic map of sections of the western part of the Gateway district, Mesa County, Colorado and Grand County, Utah. Scale 1:24,000.

Bulletin 1042-F: Heyl, A. V., 1957, Zoning of the Bitter Creek vanadium-uranium deposit near Uravan, Colorado. 15 p., 4 figs.

Professional Paper 316-A: Joesting, H. R. and Byerly, P. E., 1958, Regional geophysical investigations in the Uravan area, Colorado. 17 p., 3 pls., 5 figs.

Map MF-169: Boardman, R. L., Litsey, L. R., and Bowers, H. E., 1958, Exploration for vanadium-uranium deposits by the U. S. Geological Survey in the Club Mesa area, Uravan district, Colorado. Scale 1:7,200.

Bulletin 1084-E: Newman, W. L. and Elston, D. P., 1959, Distribution of chemical elements in the Salt Wash member of the Morrison formation, Jo Dandy area, Montrose County, Colorado. 34 p., 3 figs.

Professional Paper 400-B, p. B252-B256: Joesting, H. R. and Case, J. E., 1960, Salt anticlines and deep-seated structures in the Paradox Basin, Colorado and Utah.

_____, p. B261-B265: Elston, D. P. and Landis, E. R., 1960, Pre-Cutler unconformities and early growth of the Paradox Valley and Gypsum Valley salt anticlines.

Western San Juan Mountains, Colorado

The area studied by the Survey's Western San Juan Mountains project is at the eastern edge of the Colorado Plateau and extends into the mountains themselves. Most of the Survey's investigations were of the Plateau-type deposits in sandstones. Reports on studies in the area are:

Map MF-96: Bush, A. L., Bromfield, C. S., and Pierson, C. T., 1956, Preliminary geologic map of the Placerville, Colorado quadrangle. Scale 1:24,000.

Map MF-223: Bush, A. L., Marsh, P. T., and Taylor, R. B., 1959, Preliminary geologic map of the Little Cone quadrangle, Colorado. Scale 1:24,000.

Bulletin 1072-E: Bush, A. L., Bromfield, C. S. and Pierson, C. T., 1959, Areal geology of the Placerville quadrangle, San Miguel County, Colorado. 86 p., 5 pls., 4 figs.

Bulletin 1082-G: Bush, A. L., Marsh, P. T., and Taylor, R. B., in press, Areal geology of the Little Cone quadrangle, Colorado.

Montezuma County, Colorado

Preliminary geologic maps of five quadrangles, mapped as part of the Survey's uranium investigations in the Ute Mountains, have been published at a scale of 1:24,000. They are:

Map MF-132: Ekren, E. B. and Houser, F. N., 1957, Preliminary geologic map of the Sentinel Peak NW quadrangle, Colorado.

Map MF-216: Houser, F. N. and Ekren, E. B., 1959, Preliminary geologic map of the Moqui SW quadrangle, Colorado.

Map MF-217: Ekren, E. B. and Houser, F. N., 1959, Preliminary geologic map of the Cortez SW quadrangle, Colorado.

Map MF-221: _____, 1959, Preliminary geologic map of the Moqui SE quadrangle, Colorado.

Map MF-224: _____, 1959, Preliminary geologic map of the Sentinel Peak NE quadrangle, Colorado.

San Juan County, Utah

San Juan County, Utah, which lies east of the Colorado River and south of 38°30' north latitude, contains a number of uranium mining districts. Among these are Lisbon Valley, La Sal Creek, Sage Plain, Abajo Mountains, Elk Ridge, White Canyon, Red House Cliffs and Clay Hills north of the San Juan River, and Monument Valley south of that stream.

In 1947 little geologic information on San Juan County was available and accordingly much of the Survey's effort in that area was devoted to geologic mapping. As no topographic maps were published until 1952, much of the early mapping was done by photogeologic methods. A total of 29 preliminary geologic maps and 71 photogeologic maps of 7½-minute quadrangles wholly or mostly within San Juan County have been published at a scale of 1:24,000.

Preliminary geologic maps are:

Map MF-123: Carter, W. D. and Gaultieri, J. L., 1957, Preliminary geologic map of the Mount Peale 1 SE quadrangle, Colorado and Utah.

Map MF-124: _____, 1957, Preliminary geologic map of the Mount Peale 1 SW quadrangle, Utah.

Map MF-140: _____, 1958, Preliminary geologic map of the Mount Peale 1 NW quadrangle, Utah.

Map MF-142: Weir, G. W. and Kennedy, W. C., 1958, Preliminary geologic map of the Mount Peale 2 SW quadrangle, Utah.

Map MF-144: Weir, G. W. and Dodson, C. L., 1958, Preliminary geologic map of the Mount Peale 3 NW quadrangle, Utah.

Map MF-145: _____, 1958, Preliminary geologic map of the Mount Peale 3 NE quadrangle, Utah.

Map MF-146: _____, 1958, Preliminary geologic map of the Mount Peale 3 SW quadrangle, Utah.

Map MF-147: _____, 1958, Preliminary geologic map of the Mount Peale 3 SE quadrangle, Utah.

Map MF-148: _____, 1958, Preliminary geologic map of the Mount Peale 4 SW quadrangle, Utah.

Map MF-162: Witkind, I. J., 1958, Preliminary geologic map of the Verdure 2 NW quadrangle, Utah.

Map MF-163: Huff, L. C. and Lesure, F. G., 1958, Preliminary geologic map of the Verdure 2 SE quadrangle, Utah.

Map MF-164: _____, 1959, Preliminary geologic map of the Verdure 1 SW quadrangle, Utah.

Map MF-165: Lesure, F. G., Huff, L. C., and Stugard, Frederick, Jr., 1958, Preliminary geologic map of the Verdure 3 NE quadrangle, Utah.

Map MF-166: Huff, L. C. and Lesure, F. G., 1958, Preliminary geologic map of the Verdure 4 NW quadrangle, Utah.

Map MF-167: _____, 1958, Preliminary geologic map of the Verdure 3 SE quadrangle, Utah.

Map MF-168: Lesure, F. G. and Stugard, Frederick, Jr., 1958, Preliminary geologic map of the Verdure 4 SW quadrangle, Utah.

Map MF-184: Mullens, T. E., 1958, Preliminary geologic map of the Clay Hills 2 NE quadrangle, Utah.

Map MF-185: _____, 1958, Preliminary geologic map of the Clay Hills 2 NW quadrangle, Utah.

Map MF-186: _____, 1959, Preliminary geologic map of the Clay Hills 2 SW quadrangle, Utah.

Map MF-190: Lewis, R. Q., Sr. and Campbell, R. H., 1958, Preliminary geologic map of the Elk Ridge 2 NE quadrangle, Utah.

Map MF-191: _____, 1958, Preliminary geologic map of the Elk Ridge 2 NW quadrangle, Utah.

Map MF-192: _____, 1958, Preliminary geologic map of the Elk Ridge 2 SW quadrangle, Utah.

Map MF-193: _____, 1958, Preliminary geologic map of the Elk Ridge 2 SE quadrangle, Utah.

Map MF-194: _____, 1959, Preliminary geologic map of the Elk Ridge 3 NE quadrangle, Utah.

Map MF-195: _____, 1958, Preliminary geologic map of the Elk Ridge 3 NW quadrangle, Utah.

Map MF-198: _____, 1959, Preliminary geologic map of the Elk Ridge 4 SW quadrangle, Utah.

Map MF-199: _____, 1959, Preliminary geologic map of the Elk Ridge 4 NW quadrangle, Utah.

Map MF-200: _____, 1959, Preliminary geologic map of the Elk Ridge 1 SW quadrangle, Utah.

Map MF-201: _____, 1958, Preliminary geologic map of the Elk Ridge 1 NW quadrangle, Utah.

Photogeologic maps of quadrangles wholly or partly within San Juan County are:

Map I-2: Platt, J. N. 1954, Photogeologic map of the Carlisle 13 quadrangle, Utah.

Map I-4: Orkild, P. P., 1954, Photogeologic map of the Desert Lake 8 quadrangle, Utah.

Map I-6: Hackman, R. J., 1955, Photogeologic map of the Carlisle 14 quadrangle, Utah.

Map I-7: _____, 1955, Photogeologic map of the Elk Ridge 2 quadrangle, Utah.

Map I-8: Miller, C. F., 1955, Photogeologic map of the Elk Ridge 14 quadrangle, Utah.

Map I-16: Platt, J. N., 1955, Photogeologic map of the Orange Cliffs 16 quadrangle, Utah.

Map I-32: Hackman, R. J., 1955, Photogeologic map of the Elk Ridge 7 quadrangle, Utah.

Map I-33: Reed, J. C., Jr., 1955, Photogeologic map of the White Canyon 1 quadrangle, Utah.

Map I-35: Bennett, H. S., 1955, Photogeologic map of the Elk Ridge 15 quadrangle, Utah.

Map I-36: Reed, J. C., Jr., 1955, Photogeologic map of the White Canyon 2 quadrangle, Utah.

Map I-51: Marshall, C. H., 1955, Photogeologic map of the Clay Hills 1 quadrangle, Utah.

Map I-53: Orkild, P. P., 1955, Photogeologic map of the Bluff 6 quadrangle, Utah.

Map I-54: Miller, C. F., 1955, Photogeologic map of the Bluff 11 quadrangle, Utah.

Map I-55: Bennett, H. S., 1955, Photogeologic map of the Elk Ridge 10 quadrangle, Utah.

Map I-56: Reed, J. C., Jr., 1955, Photogeologic map of the Elk Ridge 11 quadrangle, Utah.

Map I-58: Marshall, C. H., 1955, Photogeologic map of the Clay Hills 8 quadrangle, Utah.

Map I-59: Platt, J. N., 1955, Photogeologic map of the Bluff 4 quadrangle, Utah.

Map I-60: Orkild, P. P., 1955, Photogeologic map of the Bluff 5 quadrangle, Utah.

Map I-61: Miller, C. F., 1955, Photogeologic map of the Bluff 8 quadrangle, Utah.

Map I-62: Marshall, C. H., 1955, Photogeologic map of the Clay Hills 7 quadrangle, Utah.

Map I-63: Miller, C. F., 1955, Photogeologic map of the Elk Ridge 16 quadrangle, Utah.

Map I-64: _____, 1955, Photogeologic map of the Bluff 1 quadrangle, Utah.

Map I-65: Marshall, C. H., 1955, Photogeologic map of the Clay Hills 11 quadrangle, Utah.

Map I-67: Detterman, J. S., 1955, Photogeologic map of the Carlisle 2 quadrangle, Utah.

Map I-68: Bates, C. E., 1955, Photogeologic map of the Carlisle 3 quadrangle, Utah.

Map I-71: _____, 1955, Photogeologic map of the Carlisle 6 quadrangle, Utah.

Map I-72: Sable, V. H., 1955, Photogeologic map of the Carlisle 7 quadrangle, Utah.

Map I-73: Detterman, J. S., 1955, Photogeologic map of the Carlisle 10 quadrangle, Utah.

Map I-74: Platt, J. N., 1955, Photogeologic map of the Carlisle 11 quadrangle, Utah.

Map 1-76: Hackman, R. J., 1955, Photogeologic map of the Carlisle 15 quadrangle, Utah.

Map I-78: Marshall, C. H., 1955, Photogeologic map of the Clay Hills 10 quadrangle, Utah.

Map I-79: Orkild, P. P., 1955, Photogeologic map of the Clay Hills 9 quadrangle, Utah.

Map I-80: _____, 1955, Photogeologic map of the Bluff 12 quadrangle, Utah.

Map I-82: Miller, C. F., 1955, Photogeologic map of the Elk Ridge 1 quadrangle, Utah.

Map I-90: Hackman, R. J., 1955, Photogeologic map of the Aneth 1 quadrangle, Utah and Colorado.

Map I-91: _____, 1955, Photogeologic map of the Aneth 2 quadrangle, Utah.

Map I-92: _____, 1955, Photogeologic map of the Aneth 3 quadrangle, Utah.

Map I-93: _____, 1955, Photogeologic map of the Aneth 4 quadrangle, Utah.

Map I-94: _____, 1955, Photogeologic map of the Aneth 5 quadrangle, Utah.

Map I-95: _____, 1955, Photogeologic map of the Aneth 6 quadrangle, Utah.

Map I-96: _____, 1955, Photogeologic map of the Aneth 7 quadrangle, Utah.

Map I-97: _____, 1955, Photogeologic map of the Aneth 8 quadrangle, Utah and Colorado.

Map I-98: Detterman, J. S. and Reed, J. C., Jr., 1955, Photogeologic map of the Elk Ridge 6 quadrangle, Utah.

Map I-125: Pillmore, C. L. and Reed, J. C., Jr., 1956, Photogeologic map of the Elk Ridge 3 quadrangle, Utah.

Map I-126: Miller, C. F., 1956, Photogeologic map of the Elk Ridge 8 quadrangle, Utah.

Map I-127: _____, 1956, Photogeologic map of the Elk Ridge 9 quadrangle, Utah.

Map I-150: Orkild, P. P., 1956, Photogeologic map of the White Canyon 8 quadrangle, Utah.

Map I-151: Detterman, J. S. and Platt, J. N., 1956, Photogeologic map of the Elk Ridge 4 quadrangle, Utah.

Map I-152: Sable, V. H., 1956, Photogeologic map of the Elk Ridge 5 quadrangle, Utah.

Map I-157: Hackman, R. J., 1956, Photogeologic map of the Mount Peale 9 quadrangle, Utah and Colorado.

Map I-158: _____, 1956, Photogeologic map of the Mount Peale 10 quadrangle, Utah.

Map I-159: Hackman, R. J. and Tolbert, G. E., 1956, Photogeologic map of the Mount Peale 11 quadrangle, Utah.

Map I-163: Orkild, P. P., 1956, Photogeologic map of the White Canyon 7 quadrangle, Utah.

Map I-165: Hackman, R. J., 1956, Photogeologic map of the Mount Peale 1 quadrangle, Utah and Colorado.

Map I-170: Orkild, P. P., 1956, Photogeologic map of the White Canyon 4 quadrangle, Utah.

Map I-172: Hackman, R. J., 1956, Photogeologic map of the Mount Peale 4 quadrangle, Utah.

Map I-173: _____, 1956, Photogeologic map of the Mount Peale 6 quadrangle, Utah.

Map I-174: _____, 1956, Photogeologic map of the Mount Peale 8 quadrangle, Utah.

Map I-176: _____, 1956, Photogeologic map of the Mount Peale 16 quadrangle, Utah.

Map I-180: Tolbert, G. E., 1956, Photogeologic map of the Carlisle 1 quadrangle, Utah.

Map I-181: Marshall, C. H., 1956, Photogeologic map of the Bluff 3 quadrangle, Utah.

Map I-183: Hackman, R. J., 1956, Photogeologic map of the Mount Peale 7 quadrangle, Utah.

Map I-185: _____, 1956, Photogeologic map of the Navajo Mountain 15 quadrangle, Utah.

Map I-195: Orkild, P. P., 1956, Photogeologic map of the White Canyon 3 quadrangle, Utah.

Map I-233: Hackman, R. J., 1957, Photogeologic map of the Navajo Mountain 10 quadrangle, Utah.

Map I-238: _____, 1957, Photogeologic map of the Navajo Mountain 14 quadrangle, Utah and Arizona.

Map I-240: Tolbert, G. E., 1957, Photogeologic map of the Mount Peale 5 quadrangle, Utah.

Map I-241: _____, 1957, Photogeologic map of the Mount Peale 12 quadrangle, Utah.

Map I-242: _____, 1957, Photogeologic map of the Mount Peale 13 quadrangle, Utah.

Map I-229: Olson, A. B., 1958, Photogeologic map of the Navajo Mountain 13 quadrangle, Utah.

Book reports on uranium investigations in San Juan County are:

Circular 217: Benson, W. E., Trites, A. F., Jr., Beroni, E. P., and Feeger, J. A., 1952, Preliminary report on the White Canyon area, San Juan County, Utah. 10 p., 1 pl., 2 figs.

Bulletin 1009-H: Trites, A. F., Jr., and Chew, R. T., 3rd, 1955, Geology of the Happy Jack mine, White Canyon area, San Juan County, Utah. 14 p., 2 pls., 2 figs.

Professional Paper 300, p. 281-284: Trites, A. F., Jr., Finnell, T. L., and Thaden, R. E., 1956, Uranium deposits in the White Canyon area, San Juan County, Utah.

Bulletin 1021-E: Sears, J. D., 1956, Geology of Comb Ridge and vicinity north of the San Juan River, San Juan County, Utah. 41 p., 4 pls., 2 figs.

Bulletin 1046-H: Trites, A. F., Jr. and Hadd, G. A., 1958, Geology of the Jomac mine, White Canyon area, San Juan County, Utah. 17 p., 3 pls., 5 figs.

Professional Paper 316-C: Byerly, P. E. and Joesting, H. R., 1959, Regional geophysical characteristics of the Lisbon Valley area, Utah and Colorado. 12 p., 4 pls., 5 figs.

Bulletin 1085-B: Froelich, A. J. and Kleinhampl, F. J., 1960, Botanical prospecting for uranium in the Deer Flat area, White Canyon district, San Juan County, Utah. 34 p., 1 pl., 2 figs.

Bulletin 1087-D: Lewis, R. Q., Sr., and Trimble, D. E., 1959, Geology and uranium deposits of Monument Valley, San Juan County, Utah. 27 p., 4 pls., 6 figs.

Bulletin 1087-H: Mullens, T. E., 1960, Geology of the Clay Hills area, San Juan County, Utah. 78 p., 1 pl., 2 figs.

Utah, except San Juan County

In addition to San Juan County, the Utah portion of the Colorado Plateau region includes approximately the southern half of Grand County and most of Emery, Wayne, Garfield, and Kane Counties. The area includes the San Rafael Swell and the Henry Mountains, and the Orange Cliffs, Circle Cliffs, Capitol Reef, and Vermilion Cliffs uranium districts.

Preliminary geologic quadrangle maps: A total of 23 preliminary geologic maps of 7½-minute quadrangles in the region have been published at a scale of 1:24,000. Of these, 22 form a contiguous block that includes much of the Circle Cliffs and Capitol Reef districts. The maps are:

Map MF-100: Smith, J. F., Jr., Huff, L. C., Hinrichs, E. N., and Luedke, R. G., 1957, Preliminary geologic map of the Loa 1 NE quadrangle, Utah.

Map MF-101: _____, 1957, Preliminary geologic map of the Loa 1 SE quadrangle, Utah.

Map MF-102: _____, 1957, Preliminary geologic map of the Loa 4 NE quadrangle, Utah.

Map MF-103: _____, 1957, Preliminary geologic map of the Notom 1 SW quadrangle, Utah.

Map MF-104: _____, 1957, Preliminary geologic map of the Notom 2 NE quadrangle, Utah.

Map MF-105: _____, 1957, Preliminary geologic map of the Notom 2 NW quadrangle, Utah.

Map MF-106: _____, 1957, Preliminary geologic map of the Notom 2 SW quadrangle, Utah.

Map MF-107: _____, 1957, Preliminary geologic map of the Notom 2 SE quadrangle, Utah.

Map MF-108: _____, 1957, Preliminary geologic map of the Notom 3 NE quadrangle, Utah.

Map MF-109: _____, 1957, Preliminary geologic map of the Notom 3 NW quadrangle, Utah.

Map MF-110: _____, 1957, Preliminary geologic map of the Notom 3 SW quadrangle, Utah.

Map MF-111: _____, 1957, Preliminary geologic map of the Notom 3 SE quadrangle, Utah.

Map MF-112: _____, 1957, Preliminary geologic map of the Notom 4 NE quadrangle, Utah.

Map MF-113: _____, 1957, Preliminary geologic map of the Notom 4 NW quadrangle, Utah.

Map MF-114: _____, 1957, Preliminary geologic map of the Notom 4 SW quadrangle, Utah.

Map MF-115: _____, 1957, Preliminary geologic map of the Notom 4 SE quadrangle, Utah.

Map MF-153: Davidson, E. S. and Cadigan, R. A., 1959, Preliminary geologic map of the Circle Cliffs 1 NE quadrangle, Utah.

Map MF-154: Carswell, L. D. and Davidson, E. S., 1958, Preliminary geologic map of the Circle Cliffs 1 NW quadrangle, Utah.

Map MF-155: Davidson, E. S. and Miller, G. A., 1958, Preliminary geologic map of the Circle Cliffs 1 SW quadrangle, Utah.

Map MF-156: Davidson, E. S., Brew, D. A., and Carswell, L. D., 1958, Preliminary geologic map of the Cirlce Cliffs 1 SE quadrangle, Utah.

Map MF-157: Miller, G. A. and Cadigan, R. A., 1958, Preliminary geologic map of the Circle Cliffs 2 NE quadrangle, Utah.

Map MF-158: Davidson, E. S., Brew, D. A., and Carswell, L. D., 1958, Preliminary geologic map of the Circle Cliffs 4 NE quadrangle, Utah.

Map MF-173: McKeown, F. A., Hawley, C. C., and Orkild, P. P., 1958, Preliminary geologic map of the Orange Cliffs 3 NE quadrangle, Utah.

Photogeologic maps: A total of 116 photogeologic maps of 7½-minute quadrangles in the Utah portion of the Colorado Plateau, exclusive of San Juan County, have been published at a scale of 1:24,000. A number of the quadrangles covered by these photogeologic maps were later included in the MF map series. Published photogeologic maps are:

Map I-3: Miller, C. F., 1954, Photogeologic map of the Tidwell 12 quadrangle, Utah.

Map I-5: Orkild, P. P., 1955, Photogeologic map of the Woodside 5 quadrangle, Utah.

Map I-9: Detterman, J. S., 1955, Photogeologic map of the Emery 2 quadrangle, Utah.

Map I-10: Bennett, H. S., 1955, Photogeologic map of the Emery 7 quadrangle, Utah.

Map I-11: _____, 1955, Photogeologic map of the Emery 10 quadrangle, Utah.

Map I-12: Sable, V. H., 1955, Photogeologic map of the Tidwell 7 quadrangle, Utah.

Map I-13: Kent, B. H., 1955, Photogeologic map of the Straight Cliffs 3 quadrangle, Utah.

Map I-14: Detterman, J. S., 1955, Photogeologic map of the Kaiparowits Peak 8 quadrangle, Utah.

Map I-15: _____, 1955, Photogeologic map of the Kaiparowits Peak 9 quadrangle, Utah.

Map I-17: _____, 1955, Photogeologic map of the Circle Cliffs 1 quadrangle, Utah.

Map I-18: Hackman, R. J., 1955, Photogeologic map of the Circle Cliffs 2 quadrangle, Utah.

Map I-19: Detterman, J. S., 1955, Photogeologic map of the Circle Cliffs 3 quadrangle, Utah.

Map I-20: _____, 1955, Photogeologic map of the Circle Cliffs 4 quadrangle, Utah.

Map I-21: _____, 1955, Photogeologic map of the Circle Cliffs 5 quadrangle, Utah.

Map I-22: Hackman, R. J., 1955, Photogeologic map of the Circle Cliffs 6 quadrangle, Utah.

Map I-23: _____, 1955, Photogeologic map of the Circle Cliffs 7 quadrangle, Utah.

Map I-24: Detterman, J. S., 1955, Photogeologic map of the Circle Cliffs 8 quadrangle, Utah.

Map I-25: _____, 1955, Photogeologic map of the Circle Cliffs 9 quadrangle, Utah.

Map I-26: Hackman, R. J., 1955, Photogeologic map of the Circle Cliffs 10 quadrangle, Utah.

Map I-27: _____, 1955, Photogeologic map of the Circle Cliffs 11 quadrangle, Utah.

Map I-28: Kent, B. H., Photogeologic map of the Cirele Cliffs 13 quadrangle, Utah.

Map I-29: Hackman, R. J., 1955, Photogeologic map of the Circle Cliffs 14 quadrangle, Utah.

Map I-30: _____, 1955, Photogeologic map of the Circle Cliffs 15 quadrangle, Utah.

Map I-31: _____, Photogeologic map of the Circle Cliffs 16 quadrangle, Utah.

Map I-34: Hackman, R. J. and Tolbert, G. E., 1955, Photogeologic map of the Notom 15 quadrangle, Utah.

Map I-37: Detterman, J. S., 1955, Photogeologic map of the Straight Cliffs 2 quadrangle, Utah.

Map I-38: Reed, J. C., Jr., 1955, Photogeologic map of the Straight Cliffs 9 quadrangle, Utah.

Map I-39: Kent, B. H., 1955, Photogeologic map of the Straight Cliffs 7 quadrangle, Utah.

Map I-40: Sable, V. H., 1955, Photogeologic map of the Straight Cliffs 1 quadrangle, Utah.

Map I-41: Detterman, J. S., 1955, Photogeologic map of the Navajo Mountain 6 quadrangle, Utah.

Map I-42: Hackman, R. J., 1955, Photogeologic map of the Navajo Mountain 3 quadrangle, Utah.

Map I-43: Detterman, J. S., 1955, Photogeologic map of the Navajo Mountain 4 quadrangle.

Map I-44: Bennett, H. S., 1955, Photogeologic map of the Navajo Mountain 5 quadrangle, Utah.

Map I-45: _____, 1955, Photogeologic map of the Navajo Mountain 12 quadrangle, Utah.

Map I-46: Hackman, R. J., 1955, Photogeologic map of the Mount Pennell 5 quadrangle, Utah.

Map I-47: Detterman, J. S., 1955, Photogeologic map of the Mount Pennell 11 quadrangle, Utah.

Map I-48: _____, 1955, Photogeologic map of the Mount Pennell 12 quadrangle, Utah.

Map I-49: _____, 1955, Photogeologic map of the Mount Pennell 13 quadrangle, Utah.

Map I-50: Hackman, R. J., 1955, Photogeologic map of the Mount Pennell 14 quadrangle, Utah.

Map I-52: _____, 1955, Photogeologic map of the Circle Cliffs 12 quadrangle, Utah.

Map I-57: Detterman, J. S., 1955, Photogeologic map of the Moab 5 quadrangle, Utah.

Map I-66: Bennett, H. S., 1955, Photogeologic map of the Navajo Mountain 2 quadrangle, Utah.

Map I-69: Sable, V. H., 1955, Photogeologic map of the Carlisle 4 quadrangle, Utah.

Map I-70: _____, 1955, Photogeologic map of the Carlisle 5 quadrangle, Utah.

Map I-75: Platt, J. N., 1955, Photogeologic map of the Carlisle 12 quadrangle, Utah.

Map I-77: Bennett,H. S., 1955, Photogeologic map of the Navajo Mountain 7 quadrangle, Utah.

Map I-81: Kent, B. H., 1955, Photogeologic map of the Straight Cliffs 8 quadrangle, Utah.

Map I-83: Hemphill, W. R., 1955, Photogeologic map of the Moab 16 quadrangle, Utah.

Map I-85: Detterman, J. S., 1955, Photogeologic map of the Moab 4 quadrangle, Utah.

Map I-86: _____, 1955, Photogeologic map of the Moab 6 quadrangle, Utah.

Map I-87: Sable, V. H., 1955, Photogeologic map of the Tidwell 1 quadrangle, Utah.

Map I-88: Marshall, C. H., 1955, Photogeologic map of the Tidwell 3 quadrangle, Utah.

Map I-89: Sable, V. H., 1955, Photogeologic map of the Tidwell 8 quadrangle, Utah.

Map I-99: Detterman, J. S., 1955, Photogeologic map of the Desert Lake 1 quadrangle, Utah.

Map I-100: Miller, C. F., 1955, Photogeologic map of the Desert Lake 2 quadrangle, Utah.

Map I-101: _____, 1955, Photogeologic map of the Desert Lake 6 quadrangle, Utah.

Map I-102: Condon, W. H. and Miller, C. F., 1955, Photogeologic map of the Desert Lake 7 quadrangle, Utah.

Map I-103: Cass, J. T., 1955, Photogeologic map of the Desert Lake 9 quadrangle, Utah.

Map I-104: Condon, W. H., 1955, Photogeologic map of the Desert Lake 10 quadrangle, Utah.

Map I-105: Kent, B. H., 1955, Photogeologic map of the Desert Lake 11 quadrangle, Utah.

Map I-106: Miller, C. F., 1955, Photogeologic map of the Desert Lake 12 quadrangle, Utah.

Map I-107: Bates, C. E., 1955, Photogeologic map of the Moab 11 quadrangle, Utah.

Map I-108: Bennett, H. S., 1955, Photogeologic map of the Tidwell 6 quadrangle, Utah.

Map I-109: Sable, V. H., 1955, Photogeologic map of the Tidwell 15 quadrangle, Utah.

Map I-110: _____, 1955, Photogeologic map of the Woodside 4 quadrangle, Utah.

Map I-111: Orkild, P. P., 1955, Photogeologic map of the Woodside 12 quadrangle, Utah.

Map I-112: _____, 1955, Photogeologic map of the Tidwell 4 quadrangle, Utah.

Map I-113: _____, 1955, Photogeologic map of the Tidwell 5 quadrangle, Utah.

Map I-114: Bates, C. E. and Sable, V. H., 1955, Photogeologic map of the Tidwell 9 quadrangle, Utah.

Map I-115: Orkild, P. P., 1955, Photogeologic map of the Tidwell 16 quadrangle, Utah.

Map I-116: Bates, C. E., 1955, Photogeologic map of the Moab 10 quadrangle, Utah.

Map I-117: Sable, V. H., 1955, Photogeologic map of the Moab 12 quadrangle, Utah.

Map I-118: Bergquist, W. E., 1955, Photogeologic map of the Moab 13 quadrangle, Utah.

Map I-119: Sable, V. H., 1955, Photogeologic map of the Moab 14 quadrangle, Utah.

Map I-120: Kent, B. H., 1956, Photogeologic map of the Desert Lake 14 quadrangle, Utah.

Map I-121: Hemphill, W. R. and Lewis, C. R., 1956, Photogeologic map of the Desert Lake 15 quadrangle, Utah.

Map I-122: Marshall, C. H., 1956, Photogeologic map of the Desert Lake 16 quadrangle, Utah.

Map I-123: Orkild, P. P., 1956, Photogeologic map of the Woodside 13 quadrangle, Utah.

Map I-124: Detterman, J. S., 1956, Photogeologic map of the Castle Dale 16 quadrangle.

Map I-128: Sable, V. H., 1956, Photogeologic map of the Moab 15 quadrangle, Utah.

Map I-131: Pillmore, C. L., 1956, Photogeologic map of the Springdale SE quadrangle, Utah.

Map I-132: _____, 1956, Photogeologic map of the Springdale SW quadrangle, Utah and Arizona.

Map I-134: Detterman, J. S., 1956, Photogeologic map of the Kaiparowits Peak 1 quadrangle, Utah.

Map I-135: _____, 1956, Photogeologic map of the Kaiparowits Peak 2 quadrangle, Utah.

Map I-136: _____, 1956, Photogeologic map of the Kaiparowits Peak 7 quadrangle, Utah.

Map I-137: _____, 1956, Photogeologic map of the Kanab SE quadrangle, Utah and Arizona.

Map I-138: Pillmore, C. L., 1956, Photogeologic map of the Kanab SW quadrangle, Utah and Arizona.

Map I-148: _____, 1956, Photogeologic map of the Springdale NE quadrangle, Utah.

Map I-154: Marshall, C. H., 1956, Photogeologic map of the Desert Lake 13 quadrangle, Utah.

Map I-162: Sable, V. H., 1956, Photogeologic map of the Tidwell 2 quadrangle, Utah.

Map I-164: Detterman, J. S., 1956, Photogeologic map of the Johnson SW quadrangle, Utah and Arizona.

Map I-166: Orkild, P. P., 1956, Photogeologic map of the Emery 1 quadrangle, Utah.

Map I-177: Condon, W. H., 1956, Photogeologic map of the Emery 8 quadrangle, Utah.

Map I-178: Ray, R. G., 1956, Photogeologic map of the Orange Cliffs 13 quadrangle, Utah.

Map I-184: Hackman, R. J., 1956, Photogeologic map of the Navajo Mountain 13 quadrangle, Utah and Arizona.

Map I-186: Olson, A. B., 1956, Photogeologic map of the Tidwell 10 quadrangle, Utah.

Map I-187: Ray, R. G., 1956, Photogeologic map of the Orange Cliffs 11 quadrangle, Utah.

Map I-227: Olson, A. B., 1956, Photogeologic map of the Tidwell 11 quadrangle, Utah.

Map I-244: Hackman, R. J., 1957, Photogeologic map of the Buckskin Gulch SW quadrangle, Utah and Arizona.

Map I-245: _____, 1957, Photogeologic map of the Johnson NE quadrangle, Utah.

Map I-246: Marshall, C. H., 1957, Photogeologic map of the Desert Lake 3 quadrangle, Utah.

Map I-248: Detterman, J. S. and Hackman, R. J., 1957, Photogeologic map of the Johnson SE quadrangle, Utah and Arizona.

Map I-250: Hemphill, W. R., 1958, Photogeologic map of the Mount Ellen 5 quadrangle, Utah.

Map I-251: Hackman, R. J., 1957, Photogeologic map of the Buckskin Gulch NW quadrangle, Utah.

Map I-257: Orkild, P. P., 1957, Photogeologic map of the Rainbow Point SW quadrangle, Utah.

Map I-258: Pomeroy, J. S., 1957, Photogeologic map of the Rainbow Point SE quadrangle, Utah.

Map I-259: Hackman, R. J., 1957, Photogeologic map of the Buckskin Gulch NE quadrangle, Utah.

Map I-260: Minard, J. P., 1957, Photogeologic map of the Buckskin Gulch SE quadrangle, Utah.

Map I-261: Bunnag, D. and Moustafa, G., 1957, Photogeologic map of the Emery 15 quadrangle, Utah.

Map I-262: Hemphill, W. R., 1957, Photogeologic map of the Notom 8 quadrangle, Utah.

Map I-263: Olson, A. B., 1957, Photogeologic map of the Paria SW quadrangle, Utah and Arizona.

Map I-265: McQueen, Kathleen, 1958, Photogeologic map of the Paria SE quadrangle, Utah and Arizona.

Map I-266: _____, 1958, Photogeologic map of the Paria NE quadrangle, Utah.

Map I-267: Pomeroy, J. S., 1958, Photogeologic map of the Johnson NW quadrangle, Utah.

Map I-268: McQueen, Kathleen and Ray, R. G., 1958, Photogeologic map of the Paria NW quadrangle, Utah.

Map I-275: McIntosh, W. L., 1958, Photogeologic map of the Cockscomb SE quadrangle, Utah.

Map I-278: Hackman, R. J., 1959, Photogeologic map of the Coach Creek NE quadrangle, Utah and Colorado.

Map I-279: _____, 1959, Photogeologic map of the Coach Creek SE quadrangle, Utah and Colorado.

Map I-280: Hemphill, W. R., 1959, Photogeologic map of the Mount Ellen 4 quadrangle, Utah.

Map I-294: _____, 1959, Photogeologic map of the Notom 1 quadrangle, Utah.

Map I-295: Marshall, C. H., 1959, Photogeologic map of the Desert Lake 4 quadrangle, Utah.

Map I-302: Hemphill, W. R., 1960, Photogeologic map of the Notom 2 quadrangle, Utah.

Book reports: The following book reports on the Survey's uranium investigations in the Utah portion of the Colorado Plateau, exclusive of San Juan County, have been published:

Professional Paper 228: Hunt, C. B., assisted by Paul Averitt and R. L. Miller, 1953, Geology and geography of the Henry Mountains region, Utah. 234 p., 22 pls., 116 figs.

Circular 336: Finch, W. I., 1954, Geology of the Shinarump no. 1 uranium mine, Seven Mile Canyon area, Grand County, Utah. 14 p., 2 pls., 7 figs.

Bulletin 1015-H: Huff, L. C., 1955, Preliminary geochemical studies in the Capitol Reef area, Wayne County, Utah. 12 p., 3 figs.

Bulletin 1046-D: Johnson, H. S., Jr., 1957, Uranium resources of the San Rafael district, Emery County, Utah - a regional synthesis. 18 p., 1 pl., 2 figs.

Bulletin 1087-B: _____, 1959, Uranium resources of the Cedar Mountain area, Emery County, Utah - a regional synthesis. 36 p., 6 figs.

Bulletin 1087-C: _____, 1959, Uranium resources of the Green River and Henry Mountains districts, Utah - a regional synthesis. 46 p., 4 pls., 1 fig.

Bulletin 1085-C: Kleinhampl, F. J. and Koteff, Carl, 1960, Botanical prospecting for uranium in the Circle Cliffs area, Garfield County, Utah. 20 p., 2 pls., 1 fig.

## Arizona

The Survey's uranium investigations in the Arizona portion of the Colorado Plateau were carried on in three principal areas; the Paria and Kaibab plateaus in Coconino and Mohave Counties, west and north of the Colorado River; Monument Valley in Navajo County; and the Carrizo Mountains in Apache County, in the northeastern corner of the state and extending into New Mexico. Sixteen preliminary geologic maps of 7½-minute quadrangles in the area have been published at a scale of 1:24,000; of this total, four quadrangles are in the Paria and Kaibab plateau areas and 12 are in Monument Valley. Also, 23 photogeologic maps of 7½-minute quadrangles in the Paria and Kaibab plateau areas have been published at a scale of 1:24,000.

Paria and Kaibab Plateau areas: Survey publications on the Paria and Kaibab Plateau areas are:

Map MF-188: Wells, J. D., 1958, Preliminary geologic map of the House Rock Spring NE quadrangle, Arizona.

Map MF-189: _____, 1959, Preliminary geologic map of the House Rock Spring SE quadrangle, Arizona.

Map MF-214: Petersen, R. G. and Phoenix, D. A., 1959, Preliminary geologic map of the Paria Plateau NE quadrangle, Arizona.

Map MF-215: Petersen, R. G., 1959, Preliminary geologic map of the Emmett Wash NE quadrangle, Arizona.

Map I-139: Morris, R. H., 1956, Photogeologic map of the Shinarump NW quadrangle, Arizona.

Map I-140: Marshall, C. H., 1956, Photogeologic map of the Short Creek SW quadrangle, Arizona.

Map I-141: Marshall, C. H. and Pillmore, C. L., 1956, Photogeologic map of the Short Creek NW quadrangle, Arizona.

Map I-142: Pillmore, C. L., 1956, Photogeologic map of the Short Creek NE quadrangle, Arizona.

Map I-143: Marshall, C. H., 1956, Photogeologic map of the Heaton Knolls NW quadrangle, Arizona.

Map I-153: _____, 1956, Photogeologic map of the Short Creek SE quadrangle, Arizona.

Map I-160: _____, 1956, Photogeologic map of the Fredonia SW quadrangle, Arizona.

Map I-169: McQueen, Kathleen, 1956, Photogeologic map of the Lees Ferry SE quadrangle, Arizona.

Map I-171: Minard, J. P., 1956, Photogeologic map of the Paria Plateau SW quadrangle, Arizona.

Map I-182: _____, 1956, Photogeologic map of the Paria Plateau NW quadrangle, Arizona.

Map I-189: Detterman, J. S., 1956, Photogeologic map of the Lees Ferry SW quadrangle, Arizona.

Map I-190: _____, 1956, Photogeologic map of the Emmett Wash NE quadrangle, Arizona.

Map I-191: Marshall, C. H., 1956, Photogeologic map of the Paria Plateau SE quadrangle, Arizona.

Map I-192: Minard, J. P., 1956, Photogeologic map of the Emmett Wash NW quadrangle, Arizona.

Map I-193: _____, 1956, Photogeologic map of the Tanner Wash NW quadrangle, Arizona.

Map I-194: Marshall, C. H., 1956, Photogeologic map of the Jacob Lake NE quadrangle, Arizona.

Map I-196: McQueen, Kathleen, 1957, Photogeologic map of the Lees Ferry NW quadrangle, Arizona.

Map I-198: Minard, J. P., 1956, Photogeologic map of the House Rock Spring NE quadrangle, Arizona.

Map I-199: McQueen, Kathleen, 1956, Photogeologic map of the House Rock Spring SE quadrangle, Arizona.

Map I-222: _____, 1957, Photogeologic map of the Lees Ferry NE quadrangle, Arizona.

Map I-228: _____, 1956, Photogeologic map of the Paria Plateau NE quadrangle, Arizona.

Map I-253: Minard, J. P., 1957, Photogeologic map of the House Rock Spring NW quadrangle, Arizona.

Map I-254: Pomeroy, J. S., 1957, Photogeologic map of the House Rock Spring SW quadrangle, Arizona.

Map I-255: McQueen, Kathleen, 1957, Photogeologic map of the Shinarump NE quadrangle, Arizona.

Monument Valley: Survey publications on its uranium investigations in Monument Valley, Arizona are:

Map MF-84: Witkind, I. J. and others, 1957, Preliminary geologic map of the Boot Mesa NW quadrangle, Arizona and Utah.

Map MF-85: _____, 1957, Preliminary geologic map of the Boot Mesa NE quadrangle, Arizona and Utah.

Map MF-86: _____, 1957, Preliminary geologic map of the Boot Mesa SE quadrangle, Arizona.

Map MF-87: _____, 1957, Preliminary geologic map of the Boot Mesa SW quadrangle, Arizona.

Map MF-88: _____, 1957, Preliminary geologic map of the Agathla Peak NW quadrangle, Arizona and Utah.

Map MF-89: _____, 1957, Preliminary geologic map of the Agathla Peak NE quadrangle, Arizona and Utah.

Map MF-90: _____, 1957, Preliminary geologic map of the Agathla Peak SE quadrangle, Arizona.

Map MF-91: _____, 1957, Preliminary geologic map of the Agathla Peak SW quadrangle, Arizona.

Map MF-92: _____, 1956, Preliminary geologic map of the Dinnehotso NW quadrangle, Arizona and Utah.

Map MF-93: _____, 1956, Preliminary geologic map of the Dinnehotso NE quadrangle, Arizona and Utah.

Map MF-94: _____, 1956, Preliminary geologic map of the Dinnehotso SE quadrangle, Arizona.

Map MF-95: _____, 1956, Preliminary geologic map of the Dinnehotso SW quadrangle, Arizona.

Professional Paper 300, p. 233-237: Witkind, I. J., 1956, Channels and related swales at the base of the Shinarump conglomerate, Monument Valley, Arizona.

Bulletin 1030-C: Witkind, I. J., 1956, Uranium deposits at the base of the Shinarump conglomerate, Monument Valley, Arizona. 32 p., 2 pls., 16 figs.

Carrizo Mountains: The Carrizo Mountains area was one of the earliest in Arizona to be investigated by the Survey as a possible source of uranium. Publications on the area are:

Circular 111: Stokes, W. L., 1951, Carnotite deposits in the Carrizo Mountains area, Navajo Indian Reservation, Apache County, Arizona and San Juan County, New Mexico. 5 p., 1 pl.

Map OM-160: Strobell, J. D., Jr., 1956, Geology of the Carrizo Mountains area in northeastern Arizona and northwestern New Mexico. Scale 1:48,000.

New Mexico

As a producer of uranium the New Mexico portion of the Colorado Plateau developed later than other parts of the Colorado Plateau, and the Survey did little work in the region, other than that of a reconnaissance nature, until about 1955. Investigations begun under the sponsorship of the Division of Raw Materials are continuing under the Survey's direct appropriation. Survey publications on the region are:

Circular 264: Cannon, H. L., 1953, Geobotanical reconnaissance near Grants, New Mexico. 8 p., 4 figs.

Professional Paper 300, p. 299-302: Hilpert, L. S. and Freeman, V. L., Guides to uranium deposits in the Morrison formation, Gallup-Laguna area, New Mexico.

Bulletin 1030-J: Freeman, V. L. and Hilpert, L. S., 1956, Stratigraphy of the Morrison formation in part of northwestern New Mexico. 26 p., 4 figs.

Map MF-133: Moench, R. H. and Puffett, W. P., 1957, Preliminary geologic map of the Laguna 4 NW quadrangle, New Mexico. Scale 1:24,000.

Map MF-134: _____, 1957, Preliminary geologic map of the Laguna 4 SW quadrangle, New Mexico. Scale 1:24,000.

Professional Paper 400-B, p. B52-B54: Truesdell, A. H., and Weeks, A. D., 1960, Paragenesis of uranium ores in Todilto limestone near Grants, New Mexico.

_____, p. B54-B55: Granger, H. C., 1960, Pitchblende identified in sandstone-type uranium deposit in the central part of the Ambrosia Lake district, New Mexico.

Black Hills, South Dakota and Wyoming

The Survey's uranium program in the Black Hills followed its

investigations of beryllium in that area. The first uranium studies were in the Southern Black Hills, largely in Fall River and Custer Counties, South Dakota, where carnotite was discovered in 1952. Investigations in the Northern Black Hills were started in 1955.

## Southern Black Hills

### Preliminary geologic maps

The following preliminary geologic maps of parts of 7½-minute quadrangles in the Southern Black Hills have been published at a scale of 1:7,200:

Map MF-55: Gott, G. B. and Schnabel, R. W., 1956, Preliminary geologic map of the northwest part of the Edgemont NE quadrangle, South Dakota.

Map MF-56: _____, 1956, Preliminary geologic map of the northeast part of the Edgemont NE quadrangle, South Dakota.

Map MF-57: _____, 1956, Preliminary geologic map of the east-central part of the Edgemont NE quadrangle, South Dakota.

Map MF-58: _____, 1956, Preliminary geologic map of the west-central part of the Edgemont NE quadrangle, South Dakota.

Map MF-59: _____, 1956, Preliminary geologic map of the southwest part of the Edgemont NE quadrangle, South Dakota.

Map MF-60: _____, 1956, Preliminary geologic map of the southeast part of the Edgemont NE quadrangle, South Dakota.

Map MF-61: Bell, Henry and Post, E. V., 1957, Preliminary geologic map of the northwest part of the Flint Hill quadrangle, South Dakota.

Map MF-62: _____, 1957, Preliminary geologic map of the northeast part of the Flint Hill quadrangle, South Dakota.

Map MF-63: _____, 1957, Preliminary geologic map of the east-central part of the Flint Hill quadrangle, South Dakota.

Map MF-64: _____, 1957, Preliminary geologic map of the west-central part of the Flint Hill quadrangle, South Dakota.

Map MF-65: _____, 1957, Preliminary geologic map of the southwest part of the Flint Hill quadrangle, South Dakota.

Map MF-66: _____, 1957, Preliminary geologic map of the southeast part of the Flint Hill quadrangle, South Dakota.

Map MF-67: Wilmarth, V. R. and Smith, R. D., 1957, Preliminary geologic map of the west-central part of the Minnekahda quadrangle, South Dakota.

Map MF-68: _____, 1957, Preliminary geologic map of the east-central part of the Minnekahda quadrangle, South Dakota.

Map MF-69: _____, 1957, Preliminary geologic map of the southeast part of the Minnekahda quadrangle, South Dakota.

Map MF-70: _____, 1957, Preliminary geologic map of the southwest part of the Minnekahda quadrangle, South Dakota.

Map MF-71: Schnabel, R. W. and Charlesworth, L. J., Jr., 1958, Preliminary geologic map of the west-central part of the Burdock quadrangle, South Dakota.

Map MF-72: _____, 1958, Preliminary geologic map of the northeast part of the Burdock quadrangle, South Dakota.

Map MF-73: _____, 1958, Preliminary geologic map of the northwest part of the Burdock quadrangle, South Dakota.

Map MF-74: _____, 1958, Preliminary geologic map of the east-central part of the Burdock quadrangle, South Dakota.

Map MF-75: _____, 1958, Preliminary geologic map of the southeast part of the Burdock quadrangle, South Dakota.

Map MF-77: Brobst, D. A., 1958, Preliminary geologic map of the northeast part of the Dewey quadrangle, South Dakota.

Map MF-78: _____, 1958, Preliminary geologic map of the east-central part of the Dewey quadrangle, South Dakota.

Map MF-207: Post, E. V. and Cuppels, N. P., 1959, Preliminary geologic and structure map of the northwest part of the Cascade Springs quadrangle, South Dakota.

Map MF-208: _____, 1959, Preliminary geologic and structure map of the northeast part of the Cascade Springs quadrangle, South Dakota.

Map MF-209: _____, 1959, Preliminary geologic and structure map of the west-central part of the Cascade Springs quadrangle, South Dakota.

Map MF-210: Post, E. V. and Lane, D. W., 1959, Preliminary geologic and structure map of the east-central part of the Cascade Springs quadrangle, South Dakota.

Map MF-211: Post, E. V., 1959, Preliminary geologic and structure map of the southwest part of the Cascade Springs quadrangle, South Dakota.

Map MF-212: _____, 1959, Preliminary geologic and structure map of the southeast part of the Cascade Springs quadrangle, South Dakota.

Other publications on the Southern Black Hills:

Circular 175: Page, L. R. and Redden, J. A., 1952, The carnotite prospects of the Craven Canyon area, Fall River County, South Dakota. 18 p., 1 pl., 2 figs.

Map MF-39: Braddock, W. A., 1955, Map showing distribution and occurrence of uranium deposits in part of the Edgemont mining district, Fall River County, South Dakota. Scale 1:48,000.

Bulletin 1009-G: Bell, Henry and Bales, W. E., 1955, Uranium deposits in Fall River County, South Dakota. 23 p., 5 pls., 6 figs.

Professional Paper 300, p. 345-349: Bell, Henry, Gott, G. B., Post, E. V., and Schnabel, R. W., 1956, Lithologic and structural controls of uranium deposition in the Southern Black Hills.

Bulletin 1046-A: Gott, G. B., 1956, Inferred relationship of some uranium deposits and calcium carbonate cement in Southern Black Hills. 8 p., 4 figs.

Bulletin 1063-A: Braddock, W. A., 1957, Stratigraphic and structural controls of uranium deposits on Long Mountain, South Dakota. 11 p., 4 pls., 4 figs.

## Northern Black Hills

The following reports on the Survey's uranium investigations in the Northern Black Hills have been published:

Bulletin 1021-I: Robinson, C. S., 1956, Geology of Devils Tower National Monument. 14 p., 1 pl., 3 figs.

Map MF-121: Robinson, C. S. and Goode, H. D., 1957, Preliminary geologic map of the Hulett Creek mining area, Crook County, Wyoming. Scale 1:6,000.

Map MF-180: Cuppels, N. P. and Conwell, F. R., 1958, Preliminary geologic map of the southwest part of the Clifton quadrangle, Wyoming. Scale 1:7,200.

Map OM-191: Mapel, W. J., Robinson, C. S., and Theobald, P. K., 1959, Geologic and structure map of the northern and western flanks of the Black Hills, Wyoming, Montana and South Dakota. Scale 1:96,000.

Map MF-218: Mapel, W. J. and Gott, G. B., 1958, Diagrammatic restored section of the Inyan Kara group, Morrison formation, and Unkpapa sandstone on the western side of the Black Hills, Wyoming and South Dakota. Scale 1:253,440.

Bulletin 1081-B: Waage, K. M., 1959, Stratigraphy of the Inyan Kara group in the Black Hills. 80 p., 1 pl., 5 figs.

Bulletin 1082-J: Bergendahl, M. H., Davis, R. E., and Izett, G. A., in press, Geology and mineral resources of the Carlile quadrangle, Wyoming.

## Wyoming

The first uranium investigations made by the Survey in Wyoming, other than reconnaissance studies, were in the Pumpkin Buttes area in the Powder River Basin. Detailed geologic investigations in the Gas Hills and Poison Basin areas were started in 1955, and since that time other uranium-producing areas in the state have been studied. Publications on sandstone-type deposits in Wyoming are:

Circular 176: Love, J. D., 1952, Preliminary report on uranium deposits in the Pumpkin Buttes area, Powder River Basin, Wyoming. 37 p., 3 pls.

Circular 338: Troyer, M. L., McKay, E. J., Soister, P. E. and Wallace, S. R., 1954, Summary of investigations of uranium deposits in the Pumpkin Buttes area, Jackson and Campbell Counties, Wyoming. 17 p., 2 pls., 5 figs.

Circular 344: Vine, J. D. and Pritchard, G. E., 1954, Uranium in the Poison Basin area, Carbon County, Wyoming. 8 p., 3 figs.

Bulletin 1009-A: Wilmarth, V. R. and Johnson, D. H., 1954, Uranophane at the Silver Cliff mine, Lusk, Wyoming. 12 p., 2 pls., 1 fig.

Circular 352: Love, J. D., 1954, Preliminary report on uranium in the Gas Hills area, Fremont and Natrona Counties, Wyoming. 11 p., 3 figs.

Professional Paper 300, p. 337-344: Vine, J. D., 1956, Geology of uranium in basins of Tertiary age in Wyoming and the northern Great Plains.

_____, p. 371-374: Sharp, W. N., McKeown, F. A., and McKay, E. J., 1956, Geology and uranium deposits of the Pumpkin Buttes area, Powder River Basin, Wyoming.

Map MF-83: Zeller, H. D., Soister, P. E., and Hyden, H. J., 1956, Preliminary geologic map of the Gas Hills uranium district, Fremont and Natrona Counties, Wyoming. Scale 1:31,680.

Map OM-180: Van Houten, F. B. and Weitz, J. L., 1956, Geologic map of the eastern Beaver Divide-Gas Hills area, Fremont and Natrona Counties, Wyoming. Scale 1:63,680.

Map MF-98: Sharp, W. N. and White, A. M., 1957, Preliminary geologic map of the Pumpkin Buttes area, Campbell and Johnson Counties, Wyoming, showing location of uranium occurrences. Scale 1:24,000.

## Texas Coastal Plain

The Survey's studies of uranium deposits in the Texas Coastal Plain were started in 1957. One paper has been published:

Professional Paper 400-B, p. B48-B52: Weeks, A. D. and Eargle, D. H., 1960, Uranium at Palangana salt dome, Duval County, Texas.

## Other areas

Six papers, other than reports of a strictly reconnaissance nature, have been published describing sandstone-type uranium deposits in areas other than those listed above. These are:

Circular 137: Kaiser, E. P., 1951, Uraniferous quartzite, Red Bluff prospect, Gila County, Arizona. 10 p., 1 pl., 4 figs.

Circular 334: Zeller, H. D. and Baltz, E. H., Jr., 1954, Uranium-copper deposits in the Coyote district, Mora County, New Mexico. 11 p., 3 figs.

Circular 350: Klemic, Harry and Baker, R. C., 1954, Occurrence of uranium in Carbon County, Pennsylvania.

Professional Paper 300, p. 179-185: Shoemaker, E. M., Occurrence of uranium in diatremes of the Hopi Indian Reservation, Arizona, New Mexico and Utah.

Bulletin 1030-L: Tschanz, C. M., Lamb, D. C., and Fuller, F. W., 1958, Copper and uranium deposits of the Coyote district, Mora County, New Mexico. 56 p., 11 pls., 7 figs.

Bulletin 1046-P: Granger, H. C. and Raup, R. B., 1959, Uranium deposits in the Dripping Spring quartzite, Gila County, Arizona. 72 p., 4 pls., 19 figs.

# URANIUM IN VEINS, IGNEOUS ROCKS, AND RELATED DEPOSITS

Early in the search for uranium deposits it was thought that large vein-type deposits might be found in the United States, and areas in which such deposits might be expected to occur were investigated under the sponsorship of the Division of Raw Materials. The results of these investigations, though somewhat disappointing from an immediate economic standpoint, are of great scientific interest and value. In 1952 the Division of Research began sponsorship of a long-range study of the distribution of uranium in igneous rocks, which has provided a great deal of basic data on the emplacement of the element in rocks of that type.

## General publications

Publications of a general nature on uranium in veins and igneous rocks are:

Professional Paper 300, p. 55-64: Neuerburg, G. J., 1956, Uranium in igneous rocks in the United States.

_____, p. 65-74: Larsen, E. S., Jr., Phair, George, and Smith, W. L., 1956, Uranium in magmatic differentiation.

_____, p. 75-78: Coats, R. R., 1956, Uranium and certain other trace elements in felsic volcanic rocks of the Western United States.

Bulletin 1070-A: Larsen, E. S., Jr., and Schmidt, R. G., 1958, A reconnaissance of the Idaho batholith and comparison with the Southern California batholith. 33 p., 1 pl., 4 figs.

Map I-309: Merewether, E. A., 1960, Geologic map of the igneous and metamorphic rocks of Colorado showing location of uranium deposits. Scale 1:500,000.

Map I-310: _____, 1960, Geologic map of the igneous and metamorphic rocks of Wyoming showing location of uranium deposits. Scale 1:500,000.

Map I-311: _____, 1960, Geologic map of the igneous and metamorphic rocks of Montana showing location of uranium deposits. Scale 1:500,000.

## Publications on specific areas or mines

### California

Bulletin 1087-F: MacKevett, E. M., Jr., 1960, Geology and ore deposits of the Kern River uranium area, California. 54 p., 7 pls., 4 figs.

### Colorado Front Range

Professional Paper 223: Lovering, T. S. and Goddard, E. N., 1950, Geology and ore deposits of the Front Range, Colorado. 319 p., 30 pls., 90 figs.

Circular 186: Moore, F. B. and Butler, C. R., 1952, Pitchblende deposits of the Wood and Calhoun mines, Central City mining district, Gilpin County, Colorado. 8 p., 3 pls., 2 figs.

*Circular 213: Harrison, J. E. and Leonard, B. F., 1952, Preliminary report on the Jo Reynolds area, Lawson-Dumont district, Clear Creek County, Colorado. 9 p., 2 pls., 4 figs.

Circular 215: King, R. U., Leonard, B. F., Moore, F. B., and Pierson, C. T., 1953, Uranium in the metal-mining districts of Colorado. 10 p., 1 pl., 2 figs.

Circular 320: Adams, J. W., Gude, A. J., 3rd, and Beroni, E. P., 1953, Uranium occurrences in the Golden Gate Canyon and Ralston Creek areas, Jefferson County, Colorado. 16 p., 9 figs.

Circular 345: Wells, J. D. and Harrison, J. E., 1954, Radioactivity reconnaissance of part of north-central Clear Creek County, Colorado. 9 p., 3 figs.

Professional Paper 300, p. 105-111: Sims, P. K. and Tooker, E. W., 1956, Pitchblende deposits in the Central City district and adjacent areas, Gilpin and Clear Creek Counties, Colorado.

Professional Paper 300, p. 113-116: Adams, J. W. and Stugard, Frederick, Jr., 1956, Summary of wall-rock control of certain pitchblende deposits in Golden Gate Canyon, Jefferson County, Colorado.

Bulletin 1030-G: Adams, J. W. and Stugard, Frederick, Jr., 1956, Wall-rock control of certain pitchblende deposits in Golden Gate Canyon, Jefferson County, Colorado. 23 p., 3 pls., 6 figs.

Bulletin 1030-N: Moore, F. B., Cavender, W. S., and Kaiser, E. P., 1957, Geology and uranium deposits of the Caribou area, Boulder County, Colorado. 39 p., 6 pls., 7 figs.

Bulletin 1032-A: Sims, P. K., Osterwald, F. W., and Tooker, E. W., 1955, Uranium deposits of the Eureka Gulch area, Central City district, Gilpin County, Colorado. 31 p., 1 pl., 2 figs.

Bulletin 1032-B: Harrison, J. E. and Wells, J. D., 1956, Geology and ore deposits of the Freeland-Lamartine district, Clear Creek County, Colorado. 95 p., 10 pls., 25 figs.

Bulletin 1032-C: Drake, A. A., Jr., 1957, Geology of the Wood and West Calhoun mines, Central City district, Colorado. 42 p., 4 pls., 13 figs.

Map MF-179: Sheridan, D. W., Maxwell, C. H., Albee, A. L., and Van Horn, Richard, 1958, Preliminary map of the bedrock geology of the Ralston Buttes quadrangle, Jefferson County, Colorado. Scale 1:24,000.

Bulletin 1032-D: Sims, P. K., Phair, George, and Moench, R. H., 1958, Geology of the Copper King uranium mine, Larimer County, Colorado. 51 p., 3 pls., 16 figs.

Professional Paper 319: Harrison, J. E. and Wells, J. D., 1959, Geology and ore deposits of the Chicago Creek area, Clear Creek County, Colorado. 92 p., 13 pls., 48 figs.

Bulletin 1032-E: Wells, J. D., in press, Petrography of radioactive rocks from the Front Range Mineral Belt, Colorado.

Lake County, Colorado

Circular 321: Pierson, C. T. and Singewald, Q. D., 1954, Occurrences of uranium-bearing minerals in the St. Kevin district, Lake County, Colorado. 17 p., 8 figs.

Bulletin 1027-E: Singewald, Q. D., 1955, Sugar Loaf and St. Kevin mining districts, Colorado. 49 p., 2 pls., 8 figs.

Boulder Batholith area, Montana

Circular 277: Becraft, G. E., 1953, Preliminary report on the Comet area, Jefferson County, Montana. 8 p., 1 pl., 1 fig.

Bulletin 988-F: Roberts, W. A. and Gude, A. J., 3rd, 1953, Uranium-bearing deposits west of Clancy, Jefferson County, Montana. 21 p., 4 pls., 3 figs.

Bulletin 988-G: _____, 1953, Geology of the area adjacent to the Free Enterprise mine, Jefferson County, Montana. 13 p., 3 pls., 2 figs.

Professional Paper 300, p. 117-121: Becraft, G. E., 1956, Uranium deposits of the Boulder Batholith.

Nevada

Circular 142: Staatz, M. H. and Bauer, H. L., Jr., 1952, Virgin Valley opal district, Humboldt County, Nevada. 7 p., 3 figs.

*Circular 291: Duncan, D. C., 1953, A uranium-bearing rhyolite tuff deposit near Coaldale, Esmeralda County, Nevada. 7 p., 4 figs.

Bulletin 988-C: Staatz, M. H. and Bauer, H. L., Jr., 1953, Uranium in the West Walker River area, Lyon County, Nevada. 15 p., 4 pls., 2 figs.

Bulletin 1046-I: Trites, A. F., Jr. and Thurston, W. R., 1958, Geology of Majuba Hill, Pershing County, Nevada. 21 p., 5 pls., 1 fig.

New Mexico

Circular 189: Granger, H. C. and Bauer, H. L., Jr., 1953, Uranium occurrences on the Merry Widow claim, White Signal district, Grant County, New Mexico. 16 p.

Bulletin 1009-K: Gillerman, Elliot and Whitebread, D. H., 1955, Uranium-bearing nickel-cobalt-silver deposits, Black Hawk district, Grant County, New Mexico. 31 p., 3 pls., 9 figs.

New York

Bulletin 1074-E: Klemic, Harry, Eric, J. H., McNitt, J. R., and McKeown, F. A., 1959, Uranium in the Phillips mine-Camp Smith area, Putnam and Westchester Counties, New York. 35 p., 3 pls., 2 figs.

Utah

Bulletin 1005: Thurston, W. R., Staatz, M. H., Cox, D. C., and others, 1954, Fluorspar deposits of Utah. 53 p., 8 pls., 18 figs.

Professional Paper 300, p. 123-129: Walker, G. W. and Osterwald, F. W., 1956, Relation of secondary uranium minerals to pitchblende-bearing veins at Marysvale, Piute County, Utah.

_____, p. 131-136: Staatz, M. H. and Osterwald, F. W., 1956, Uranium in the fluorspar deposits of the Thomas Range, Utah.

Bulletin 1069: Staatz, M. H. and Osterwald, F. W., 1959, Geology of the Thomas Range fluorspar district, Juab County, Utah. 97 p., 12 pls., 11 figs.

Washington

Map MF-135: Becraft, G. E. and Weis, P. L., 1957, Preliminary geologic map of part of the Turtle Lake quadrangle, Lincoln and Stevens Counties, Washington. Scale 1:48,000.

## URANIUM IN CARBONACEOUS MATERIALS

In 1947, when the Survey's program on behalf of the Divison of Raw Materials was started, it was thought that black shales might be an important source of uranium for some contain vast quantities of the element, although in very low concentrations. Reconnaissance of the black shales of the United States and more detailed studies of the Chattanooga shale of eastern Tennessee were therefore important parts of the program in its earlier stages. Later, following extensive reconnaissance studies, the uraniferous lignites of North and South Dakota were investigated, as were also asphalts and petroleum.

### Black shales

General reports on the black shales of the United States that have been published by the Survey are:

Professional Paper 300, p. 469-476: Mapel, W. J., 1956, Uraniferous black shale in the Northern Rocky Mountains and Great Plains Regions.

_____, p. 505-510: Breger, I. A., The organic geochemistry of uranium.

Bulletin 1030-H: Mapel, W. J., 1956, Uranium in black shale deposits, Northern Rocky Mountains and Great Plains. 25 p., 2 pls., 4 figs.

Bulletin 1046-G: Becraft, G. E., 1958, Uranium in carbonaceous rocks in the Townsend and Helena Valleys, Montana. 16 p., 1 pl., 4 figs.

Bulletin 1046-L: Landis, E. R., 1959, Radioactivity and uranium content, Sharon Springs member of the Pierre shale, Kansas and Colorado, 15 p., 4 pls.

Bulletin 1046-R: Kepferle, R. C., 1959, Uranium in the Sharon Springs member of the Pierre shale, South Dakota and northwestern Nebraska. 28 p., 3 pls., 8 figs.

Professional Paper 356-A: Swanson, V. E., 1960, Oil yield and uranium content of black shales. 44 p., 21 figs.

## Chattanooga shale

Survey publications on the Chattanooga shale are:

Professional Paper 286: Hass, W. H., 1956, Age and correlation of the Chattanooga shale and the Maury formation. 47 p., 5 pls., 1 fig.

Professional Paper 300, p.457-462: Brown, Andrew, 1956, Uranium in the Chattanooga shale of eastern Tennessee.

_____, p. 463-467: Conant, L. C., 1956, Environment of deposition of the Chattanooga shale.

Bulletin 1087-E: Glover, Lynn, 1959, Stratigraphy and uranium content of the Chattanooga shale in northeastern Alabama, northwestern Georgia, and eastern Tennessee. 36 p., 5 pls., 5 figs.

Professional Paper 357: Conant, L. C. and Swanson, V. E., in press, Chattanooga shale of eastern Tennessee.

## Coal and lignite

In 1950 the emphasis in the Survey's investigations of carbonaceous materials was shifted from black shales to lignites, particularly those in the western Dakotas. Publications on lignite investigations are:

Circular 212: Vine, J. D. and Moore, G. W., 1952, Uranium-bearing coal and carbonaceous rocks in the Fall Creek area, Bonneville County, Idaho. 10 p., 1 pl., 4 figs.

Circular 251: Hail, W. J., Jr., and Gill, J. R., 1953, Results of reconnaissance for uraniferous coal, lignite, and carbonaceous shale in western Montana. 9 p., 1 fig.

Map C-33: Denson, N. M. and others, 1955, Uraniferous coal beds in parts of North Dakota, South Dakota, and Montana. Scales 1:31,680 and 1:63,360.

Map C-34: Denson, N. M., Bachman, G. O., and Zeller, H. D., 1955, Geologic map of the Cave Hills and Table Mountain area, Harding County, South Dakota. Scale 1:31,680.

Map C-35: _____, 1955, Geologic map of the Slim Buttes area, Harding County, South Dakota. Scale 1:63,360.

Map C-36: Moore, G. W. and Gill, J. R., 1955, Geologic map of the southern part of the Slim Buttes area, Harding County, South Dakota. Scale 1:31,680.

Map C-37: Zeller, H. D., 1955, Geologic map of the Bar H area, Slim Buttes, Harding County, South Dakota. Scale 1:20,000.

Bulletin 1009-I: Gill, J. R. and Moore, G. W., 1955, Carnotite-bearing sandstone in Cedar Canyon, Slim Buttes, Harding County, South Dakota. 16 p., 2 pls., 3 figs.

Map C-38: Moore, G. W., Melin, R. E., and Kepferle, R. C., 1956, Preliminary geologic map of the Chalky Buttes area, Slope County, South Dakota. Scale 1:31,680.

Professional Paper 300, p. 405-411: Vine, J. D., Uranium-bearing coal in the United States.

_____, p. 413-418: Denson, N. M. and Gill, J. R., 1956, Uranium-bearing lignite and its relation to volcanic tuffs in eastern Montana and North and South Dakota.

_____, p. 433-438: Pipiringos, G. N., 1956, Uranium-bearing coal in the central part of the Great Divide Basin, Sweetwater County, Wyoming.

_____, p. 439-444: Masursky, Harold, 1956, Trace elements in coal in the Red Desert, Wyoming.

Bulletin 1030-I: Wyant, D. G., Sharp, W. N., and Sheridan, D. M., 1956, Reconnaissance study of uranium deposits in the Red Desert, Sweetwater County, Wyoming. 72 p., 8 pls., 3 figs.

Bulletin 1036-H: Deul, Maurice and Annell, C. S., 1956, The occurrence of minor elements in the ash of low-rank coals from Texas, Colorado, North Dakota, and South Dakota. 18 p., 1 pl., 1 fig.

Bulletin 1055: Denson, N. M. and others, 1959, Uranium in coal in the United States. 315 p., 59 pls., 44 figs. Contains:

Pt. A: Denson, N. M., Introduction.

Pt. B: Denson, N. M., Bachman, G. O., and Zeller, H. D., Uranium-bearing lignite in northwestern South Dakota and adjacent states.

Pt. C: Zeller, H. D. and Schopf, J. M., Core-drilling for uranium-bearing lignite in Harding and Perkins Counties, South Dakota and Bowman County, North Dakota.

Pt. D: Gill, J. R., Zeller, H. D., and Schopf, J. M., Core-drilling for uranium-bearing lignite, Mendenhall area, Harding County, South Dakota.

Pt. E: Moore, G. W., Melin, R. E., and Kepferle, R. C., Uranium-bearing lignite in southwestern South Dakota.

Pt. F: Gill, J. R., Reconnaissance for uranium in the Ekalaka lignite field, Carter County, Montana.

Pt. G: Masursky, Harold and Pipiringos, G. N., Uranium-bearing coal in the Red Desert area, Sweetwater County, Wyoming.

Pt. H: Mapel, W. J. and Hail, W. J., Jr., Tertiary geology of the Goose Creek district, Cassia County, Idaho, Box Elder County, Utah, and Elko County, Nevada.

Pt. I: Vine, J. D., Geology and uranium deposits in carbonaceous rocks of the Fall Creek area, Bonneville County, Idaho.

Pt. J: Bachman, G. O., Vine, J. D., Read, C. B., and Moore, G. W., Uranium-bearing coal and carbonaceous shale in the La Ventana Mesa area, Sandoval County, New Mexico.

## Oil and asphalt

Publications on uranium in oil and asphalt are:

Bulletin 988-E: Gott, G. B. and Hill, J. W., 1953, Radioactivity of some oil fields in southeastern Kansas. 52 p., 10 pls., 5 figs.

Professional Paper 300, p. 511-519: Hyden, H. J., 1956, Uranium and other trace metals in crude oils of the Western United States.

_____, p. 521-526: Hail, W. J., Jr., Uranium in asphalt-bearing rocks of the Western United States.

_____, p. 527-532: Pierce, A. P., Mytton, J. W., and Gott, G. B., 1956, Radioactive elements and their daughter products in the Texas panhandle and other oil and gas fields in the United States.

Bulletin 1046-E: Hail, W. J., Jr., 1957, Reconnaissance for asphalt-bearing rocks in the Western United States. 31 p., 2 figs.

Professional Paper 346-B: Bell, K. G., in press, Uranium in petroleum and rock asphalt, and data on other elements.

## URANIUM IN PHOSPHATE

In 1947 the bulk of the known uranium in the United States was in black shales and phosphates. The latter appeared to be the most likely source of the metal, as phosphate was being mined extensively for fertilizer; it was thought that uranium might be recovered as a by-product at existing mines and mills. The Survey's investigations covered both the phosphate fields in the southeastern United States and those in the Phosphoria formation of Wyoming and adjacent states.

### Southeast phosphate

Early reconnaissance showed that the phosphate fields of Middle Tennessee were too low in uranium content to justify further investigations, and that the abandoned fields near Charleston, South Carolina were too small to be of interest. Investigations therefore were concentrated on the fields in the Bone Valley formation in central Florida, although some of the studies extended into northern Florida and Georgia. Survey publications on the southeastern phosphate fields are:

#### South Carolina

Map GP-123: Meuschke, J. L., 1955, Airborne radioactivity survey of the Edisto Island area, Berkeley, Charleston, Colleton, and Dorchester Counties, South Carolina. Scale approx. 1:63,360.

Bulletin 1079: Malde, H. E., 1959, Geology of the Charleston phosphate area, South Carolina. 105 p., 10 pls., 13 figs.

## Florida

Circular 230: Moxham, R. M., 1954, Airborne radioactivity surveys for phosphate in Florida. 4 p., 8 pls., 1 fig.

Map GP-119: _____, 1954, Airborne radioactivity survey in the Folkston area, Charlton County, Georgia and Nassau County, Florida. Scale approx. 1:63,360.

Map GP-121: Meuschke, J. L., 1954, Airborne radioactivity survey of the Fort Myers area, Charlotte and Lee Counties, Florida. Scale approx. 1:63,360.

Map GP-122: _____, 1955, Airborne radioactivity survey of the Gardner area, DeSoto, Hardee, Manatee, and Sarasota Counties, Florida. Scale approx. 1:63,360.

Professional Paper 300, p. 489-494: Cathcart, J. B., 1956, Distribution and occurrence of uranium in the calcium phosphate zone of the land-pebble district of Florida.

_____, p. 495-505: Altschuler, Z. S., Jaffe, E. D., and Cuttitta, Frank, 1956, The aluminum phosphate zone of the Bone Valley formation, Florida, and its uranium deposits.

Bulletin 1030-B: Bergendahl, M. H., 1956, Stratigraphy of parts of Hardee and DeSoto Counties, Florida. 34 p., 4 pls., 6 figs.

Professional Paper 314-D: Altschuler, Z. S., Clarke, R. S., Jr., and Young, E. J., Geochemistry of uranium in apatite and phosphorite. 46 p., 3 pls., 13 figs.

Bulletin 1046-J: Espenshade, G. H., 1958, Geologic features of areas of abnormal radioactivity south of Ocala, Marion County, Florida. 15 p., 4 pls.

Bulletin 1046-K: Cathcart, J. B. and McGreevy, L. J., 1959, Results of geologic exploration by core drilling, 1953, land-pebble phosphate district, Florida. 78 p., 19 pls., 1 fig.

Bulletin 1074-C: Ketner, K. B. and McGreevy, L. J., 1959, Stratigraphy of the area between Hernando and Hardee Counties, Florida. 76 p., 3 pls., 3 figs.

Bulletin 1092: Carr, W. J. and Alverson, D. C., 1959, Stratigraphy of middle Tertiary rocks in part of west-central Florida. 111 p., 3 pls., 16 figs.

## Phosphoria formation

The most extensive phosphate deposits in the United States are in the Phosphoria formation of Permian age which crops out in Idaho, Montana, Wyoming and Utah. Strategic Minerals investigations by the Survey in 1938 discovered that some beds in the formation were high in vanadium, and later it was found that some of the vanadiferous beds contained small amounts of uranium. Further studies, supported in part by the Missouri River Basin Committee of the Department of the Interior and in part by AEC, were started in 1947 to investigate the formation as a source not only of phosphate, but of vanadium, uranium, zinc, and molybdenum.

Survey publications on its investigations of the Phosphoria formation are:

Preliminary Map 3-198: Clabaugh, P. S., 1946, Map of the Permian phosphate deposits of Montana, Wyoming, Idaho, and Utah. Scale 1 inch = 16 miles.

Circular 297: Swanson, R. W., McKelvey, V. E., and Sheldon, R. P., 1953, Progress report on investigations of western phosphate deposits. 16 p., 1 pl., 11 figs.

Bulletin 988-D: Thompson, M. E., 1953, Distribution of uranium in the rich phosphate beds of the Phosphoria formation. 23 p., 12 figs.

Bulletin 1009-D: _____, 1954, Further studies of the distribution of uranium in rich phosphate beds of the Phosphoria formation. 17 p., 10 figs.

Bulletin 1015-I: Cressman, R. A. and Gulbrandsen, R. A., 1955, Geology of the Dry Valley quadrangle, Idaho. 14 p., 1 pl., 2 figs.

Bulletin 1027-A: Cressman, R. A., 1955, Physical stratigraphy of the Phosphoria formation in part of southwestern Montana. 31 p., 5 pls., 12 figs.

Professional Paper 300, p. 483-487: McKelvey, V. E. and Carswell, L. D., 1956, Uranium in the Phosphoria formation.

Bulletin 1042-A: Gulbrandsen, R. A., McLaughlin, K. P., Honkala, F. S., and Clabaugh, S. E., 1956, Geology of the Johnson Creek quadrangle, Caribou County, Idaho. 23 p., 2 pls., 1 fig.

Bulletin 1042-E: Sheldon, R. P., 1957, Physical stratigraphy of the Phosphoria formation in northwestern Wyoming. 81 p., 5 pls., 18 figs.

Bulletin 1084-D: Sheldon, R. P., 1959, Geochemistry of uranium in phosphorites and black shales of the Phosphoria formation. 31 p., 7 figs.

Professional Paper 313-A: McKelvey, V. E. and others, 1959, The Phosphoria, Park City, and Shedhorn formations in the western phosphate field. 47 p., 3 pls., 4 figs.

Professional Paper 400-B, p. B65-B66: Swanson, R. W., 1960, Phosphate and associated resources in Permian rocks of southwestern Montana.

## Stratigraphic sections of the Phosphoria formation

In 1952, 1953, and 1954 a series of Circulars containing abstracts of stratigraphic and analytical data on the Phosphoria formation were published by the Survey. In addition to their purely scientific value, these Circulars make available data that are of value to organizations working in the region, whether for phosphate or for other minerals. The Circulars are:

Circular 208: McKelvey, V. E., Davidson, D. F., O'Malley, F. W., and Smith, L. E., Stratigraphic sections of the Phosphoria formation in Idaho, 1947-48. 49 p., 1 pl., 2 figs.

Circular 209: Swanson, R. W. and others, 1953, Stratigraphic sections of the Phosphoria formation in Montana, 1947-48. 31 p., 1 pl., 1 fig.

Circular 210: McKelvey, V. E. and others, 1953, Stratigraphic sections of the Phosphoria formation in Wyoming, 1947-48. 31 p., 1 pl., 1 fig.

Circular 211: Smith, L. E., Hosford, C. S., Sears, R. S., Sprouse, D. P., and Stewart, M. D., 1952, Stratigraphic sections of the Phosphoria formation in Utah, 1947-48. 48 p., 1 pl., 1 fig.

Circular 260: Klepper, M. R., Honkala, F. S., Payne, C. A., and Ruppel, E. T., Stratigraphic sections of the Phosphoria formation in Montana, 1948. 39 p., 2 figs.

Circular 262: O'Malley, F. W., Davidson, D. F., Hoppin, R. A., and Sheldon, R. P., 1953, Stratigraphic sections of the Phosphoria formation in Idaho, 1947-48, Part 3. 43 p., 2 figs.

Circular 301: McKelvey, V. E., Armstrong, F. C., Gulbrandsen, R. A., and Campbell, R. M., 1953, Stratigraphic sections of the Phosphoria formation in Idaho, 1947-48, Part 2. 58 p., 2 figs.

Circular 302: Cressman, E. R., Wilson, W. H., Tandy, C. W., and Garmoe, W. J., 1953, Stratigraphic sections of the Phosphoria formation in Montana, 1949-50. 23 p., 2 figs.

Circular 303: Swanson, R. W., Cressman, E. R., Jones, R. S., and Replogle, B. K., 1953, Stratigraphic sections of the Phosphoria formation in Montana, 1949-50, Part 2. 21 p., 2 figs.

Circular 304: Sheldon, R. P., Warner, M. A., Thompson, M. E., and Pierce, H. W., 1953, Stratigraphic sections of the Phosphoria formation in Idaho, 1949, Part 1. 30 p., 2 figs.

Circular 305: Davidson, D. F., Smart, R. A., Pierce, H. W., and Weiser, J. D., 1953, Stratigraphic sections of the Phosphoria formation in Idaho, 1949, Part 2. 28 p., 2 figs.

Circular 306: Cheney, T. M., Smart, R. A., Waring, R. G. and Warner, M. A., 1953, Stratigraphic sections of the Phosphoria formation in Utah, 1949-51. 40 p., 2 figs.

Circular 307: Sheldon, R. P., Waring, R. G., Warner, M. A. and Smart, R. A., 1953, Stratigraphic sections of the Phosphoria formation in Wyoming, 1949-50. 45 p., 2 figs.

Circular 324: Cheney, T. M., Sheldon, R. P., Waring, R. G. and Warner, M. A., 1954, Stratigraphic sections of the Phosphoria formation in Wyoming, 1951. 22 p., 2 figs.

Circular 325: Sheldon, R. P., Cressman, E. R., Carswell, L. D., and Smart, R. A., 1954, Stratigraphic sections of the Phosphoria formation in Wyoming, 1952. 24 p., 2 figs.

Circular 326: Peterson, J. A., Gosman, R. F., and Swanson, R. W., 1954, Stratigraphic sections of the Phosphoria formation in Montana, 1951. 27 p., 2 figs.

Circular 327: Smart, R. A., Waring, R. G., Cheney, T. M., and Sheldon, R. P., 1954, Stratigraphic sections of the Phosphoria formation in Idaho, 1950-51. 12 p., 2 figs.

Circular 375: Swanson, R. W., Carswell, L. D., Sheldon, R. P., and Cheney, T. M., 1956, Stratigraphic sections of the Phosphoria formation, 1953. 30 p., 5 figs.

## URANIUM IN LIMESTONE

Four reports on uranium in limestone have been published:

*Circular 278: Love, J. D., 1953, Preliminary report on the uranium deposits of the Miller Hill area, Carbon County, Wyoming. 10 p., 1 pl.

Circular 358: _____, 1954, Uranium in the Mayoworth area, Johnson County, Wyoming. 7 p., 1 pl., 4 figs.

Bulletin 1030-K: Guilinger, R. R. and Theobald, P. K., 1957, Uranium deposits in oolitic limestone near Mayoworth, Johnson County, Wyoming. 8 p., 5 figs.

Bulletin 1074-F: Vine, J. D. and Pritchard, G. E., 1959, Geology and uranium occurrences in the Miller Hill area, Carbon County, Wyoming. 39 p., 7 pls., 5 figs.

## INVESTIGATIONS OF THORIUM AND RELATED DEPOSITS

Investigations of monazite as a source of thorium were included in the program of the Division of Raw Materials in 1947, 1948, and 1949, but were then recessed until 1952. Studies of thorium were resumed on a small scale in 1952 and continued through 1955. In 1956 the Division of Research began sponsorship of a comprehensive study of the geology and geochemistry of thorium, which is of particular interest in view of the recent renewed interest in thorium as a source material.

Survey publications in thorium and related elements are:

Map MF-4: Sharp, W. N. and Pray, L. C., 1952, Geologic studies of bastnaesite deposits of the Birthday claims, San Bernadino County, California. Scale 1:600.

Circular 202: Bates, R. G. and Wedow, Helmuth, Jr., 1953, Preliminary summary review of the thorium-bearing mineral occurrences of Alaska. 13 p., 1 pl.

Circular 237: Mertie, J. B., Jr., 1953, Monazite deposits of the southeastern Atlantic states. 31 p., 1 pl., 2 figs.

Circular 290: Christman, R. A., Heyman, A. M., Dellwig, L. F., and Gott, G. B., 1953, Thorium investigations, 1950-52, Wet Mountains, Colorado. 40 p., 5 pls., 15 figs.

Bulletin 988-H: Trites, A. F., Jr. and Tooker, E. W., 1953, Uranium and thorium deposits in east-central Idaho and southwestern Montana. 53 p., 1 pl., 11 figs.

Professional Paper 261: Olson, J. C., Shawe, D. R., Pray, L. C. and Sharp, W. N., 1954, Rare-earth deposits of the Mountain Pass district, San Bernadino County, California, with a foreword on the history of the discovery at Mountain Pass by D. F. Hewett. 75 p., 13 pls., 19 figs.

Map MF-37: Singewald, Q. D. and others, 1955, Geologic and radiometric maps of the McKinley Mountain area, Wet Mountains, Colorado. Scale 1:7,200.

Bulletin 1021-A: Fleischer, Michael, 1955, Hafnium content and hafnium-zirconium ratio in minerals and rocks. 13 p.

Bulletin 1021-C: Moxham, R. M., Walker, G. W., and Baumgardner, L. H., 1955, Geologic and airborne radioactivity studies in the Rock Corral area, San Bernadino County, California. 17 p., 2 pls., 4 figs.

Professional Paper 300, p. 375-380: Mackin, J. H. and Schmidt, R. G., 1956, Uranium- and thorium-bearing minerals in placer deposits in Idaho.

_____, p. 559-566: Twenhofel, W. S. and Buck, K. L., 1956, Geology of uranium deposits in the United States.

_____, p. 567-579: Frondel, Clifford, 1956, Mineralogy of thorium.

_____, p. 581-585: Singewald, Q. D. and Brock, M. R., 1956, Thorium deposits in the Wet Mountains, Colorado.

_____, p. 587-592: Olson, J. C. and Wallace, S. R., 1956, Thorium in the Powderhorn district, Gunnison County, Colorado.

_____, p. 593-596: Vickers, R. C., 1956, Geology and monazite content of the Goodrich quartzite, Palmer area, Marquette County, Michigan.

_____, p. 597-601: Overstreet, W. C., Cuppels, N. P., and White, A. M., 1956, Monazite in southeastern United States.

Bulletin 1027-O: Olson, J. C. and Wallace, S. R., 1956, Thorium and rare-earth minerals in the Powderhorn district, Gunnison County, Colorado. 29 p., 2 pls., 1 fig.

Bulletin 1030-F: Vickers, R. C., 1956, Geology and monazite content of the Goodrich quartzite, Palmer area, Marquette County, Michigan. 15 p., 2 pls., 3 figs.

Bulletin 1042-K: Armstrong, F. C., 1957, Dismal Swamp placer deposit, Elmore County, Idaho. 10 p., 1 pl., 3 figs.

Bulletin 1042-L: Dryden, Lincoln, 1948, Monazite in the southern Atlantic Coastal Plain. 35 p., 4 pls., 1 fig.

Bulletin 1046-B: McKeown, F. A. and Klemic, Harry, 1956, Rare-earth-bearing apatite at Mineville, Essex County, New York. 15 p., 4 figs.

Bulletin 1072-H: Christman, R. A., Brock, M. R., Pearson, R. C., and Singewald, Q. D., 1959, Geology and thorium deposits of the Wet Mountains, Colorado, a progress report. 45 p., 2 pls., 3 figs.

Bulletin 1082-A: Mertie, J. B., Jr., 1958, Zirconium and hafnium in the southeastern United States. 28 p.

Bulletin 1082-B: Klemic, Harry, Heyl, A. V., Taylor, A. R., and Stone, Jerome, 1959, Radioactive rare-earth deposit at Scrub Oaks mine, Morris County, New Jersey. 31 p., 1 pl., 6 figs.

Professional Paper 400-B, p. B55-B57: Overstreet, W. C., 1960, Metamorphic grade and abundance of $ThO_2$ in monazite.

_____, p. B168-B169: Flanagan, F. J., Smith, W. L., and Sherwood, A. M. (Battelle Memorial Institute), 1960, A comparison of two estimates of the thorium content of the Conway granite, New Hampshire.

## BERYLLIUM INVESTIGATIONS

Prior to 1947 the Survey investigated pegmatitic and non-pegmatitic deposits of beryllium as part of its Strategic Minerals studies. The program was continued under the sponsorship of the Division of Raw Materials from 1947 through 1950, when field work was completed. Survey publications on the beryllium program are:

Bulletin 945-C: Jahns, R. H., 1944, Beryllium and tungsten deposits of the Iron Mountain district, Sierra and Socorro Counties, New Mexico, with a section on the beryllium minerals by J. J. Glass. 35 p., 16 pls.,

Professional Paper 227: Hanley, J. B., Heinrich, E. W., and Page, L. R., 1950, Pegmatite investigations in Colorado, Wyoming, and Utah, 1942-44. 125 p., 17 pls., 34 figs.

Bulletin 982-D: Adams, J. W., 1953, Beryllium deposits of the Mount Antero region, Chaffee, Colorado. 25 p., 5 figs.

Circular 245: Lang, A. L., Jr., and Redden, J. A., 1953, Geology and pegmatites of part of the Fourmile area, Custer County, South Dakota. 20 p., 1 pl., 2 figs.

Professional Paper 247: Page, L. R. and others, 1953, Pegmatite investigations, 1942-45, Black Hills, South Dakota. 229 p., 45 pls., 37 figs.

Professional Paper 255: Cameron, E. N. and others, 1954, Pegmatite investigations, 1942-45, in New England. 352 p., 48 pls., 130 figs.

Bulletin 1011: Thurston, W. R., 1955, Pegmatites of the Crystal Mountain district, Larimer County, Colorado. 185 p., 13 pls., 32 figs.

Bulletin 1015-C: Sheridan, D. M., 1955, Geology of the High Climb 8 pegmatite, Custer County, South Dakota. 40 p., 1 pl., 4 figs.

Professional Paper 265: Staatz, M. H. and Trites, A. F., Jr., 1955, Geology of the Quartz Creek pegmatite district, Gunnison County, Colorado. 111 p., 8 pls., 4 figs.

Bulletin 1042-Q: Stugard, Frederick, Jr., 1956, Pegmatites of the Middletown area, Connecticut. 71 p., 10 pls., 2 figs.

Professional Paper 297-A: Sheridan, D. M., Stephens, H. G., and Norton, J. J., 1957, Geology and beryl deposits of the Peerless pegmatite, Pennington County, South Dakota. 47 p., 7 pls., 2 figs.

Bulletin 1072-I: Redden, J. A., 1959, Beryl deposits of the Beecher no. 3-Black Diamond pegmatite, Custer County, South Dakota. 23 p., 2 pls., 1 fig.

Professional Paper 318: Warner, L. A., Holser, W. T., Wilmarth, V. R. and Cameron, E. N., 1959, Occurrence of non-pegmatitic beryllium in the United States. 198 p., 5 pls., 60 figs.

Professional Paper 400-B, p. B67-B70: Norton, J. J., 1960, Hugo pegmatite, Keystone, South Dakota.

_____, p. B70-B71: Stager, H. K., 1960, A new beryllium deposit at the Mount Wheeler mine, White Pine County, Nevada.

_____, p. B71-B73: Hawley, C. C., Sharp, W. N., and Griffitts, W. R., 1960, Pre-mineralization faulting in the Lake George area, Park County, Colorado.

_____, p. B73-B74: Sharp, W. N. and Hawley, C. C., 1960, Bertrandite-bearing greisen, a new beryllium ore in the Lake George district, Colorado.

_____, p. B90-B92: Griffitts, W. R. and Oda, U., 1960, Geochemical prospecting for beryllium.

Bulletin 1082-D: Olson, J. C. and Hinrichs, E. N., 1960, Beryl-bearing pegmatites in the Ruby Mountains and other areas in Nevada and northwestern Arizona. 66 p., 5 pls., 4 figs.