ORNL/EIS-121/V3

ornl

OAK RIDGE NATIONAL LABORATORY

UNION CARBIDE

GEOLOGICAL AND GEOCHEMICAL ASPECTS OF URANIUM DEPOSITS

A Selected, Annotated Bibliography--Vol. 3

Sponsored by

GRAND JUNCTION OFFICE/DEPARTMENT OF ENERGY

OPERATED BY
UNION CARBIDE CORPORATION
FOR THE UNITED STATES
DEPARTMENT OF ENERGY

ORNL/EIS-121/V3

Contract No. W-7405-eng-26

Information Division

GEOLOGICAL AND GEOCHEMICAL ASPECTS OF URANIUM DEPOSITS

A SELECTED, ANNOTATED BIBLIOGRAPHY

Volume 3

Compiled and edited by

P. A. Garland, J. M. Thomas, M. L. Brock, and E. W. Daniel

National Uranium Resource Evaluation Program
Ecological Sciences Information Center
Information Center Complex

Sponsored by
Grand Junction Office
of the
Department of Energy

Manuscript Completed—May 1980

Date Published—June 1980

Prepared by the

OAK RIDGE NATIONAL LABORATORY
Oak Ridge, Tennessee 37830
operated by
UNION CARBIDE CORPORATION
for the
DEPARTMENT OF ENERGY

CONTENTS

HIGHLIGHTS

A bibliography of 479 references encompassing the fields of uranium and thorium geochemistry and mineralogy, geology of uranium deposits, uranium mining, and uranium exploration techniques has been compiled by the Ecological Sciences Information Center of Oak Ridge National Laboratory. The bibliography was produced for the National Uranium Resource Evaluation Program, which is funded by the Grand Junction Office of the Department of Energy.

The references contained in the bibliography have been divided into the following eight subject categories: (1) geology of deposits, (2) geochemistry, (3) genesis of deposits, (4) exploration, (5) mineralogy, (6) uranium industry, (7) reserves and resources, and (8) geology of potential uranium-bearing areas. All categories specifically refer to uranium and thorium; the last category contains basic geologic information concerning areas which the Grand Junction Office feels are particularly favorable for uranium deposition. The references are indexed by author, geographic location, quadrangle name, geoformational feature, taxonomic name, and keyword.

PREFACE

This compilation of 479 indexed and abstracted references is the third in a series of bibliographies produced in conjunction with the National Uranium Resource Evaluation (NURE) Bibliographic Data Base. The data base was created and is maintained by the Ecological Sciences Information Center (ESIC) of Oak Ridge National Laboratory for the Grand Junction Office of the Department of Energy (DOE). In addition to the Bibliographic File, ESIC maintains six other data bases for the Grand Junction Office of DOE: Uranium Mines File, Quadrangle File, Contractors' Report File, Geounit File, Reference File, and Numeric File.

The major emphasis of the NURE Bibliographic Data Base is the geology of uranium and thorium deposits, uranium and thorium geochemistry and mineralogy, the uranium industry, and uranium and thorium reserves. References concerning uranium mining and exploration techniques are also included, as are references cited in NURE contractor reports to the Grand Junction Office.

The references included in this bibliography are divided into subject categories, and the following indexes are provided to assist in finding pertinent references: author, geographic location, quadrangle name, geoformational feature, taxonomic name, and keyword. The subject categories and keywords have been revised since the second bibliography was published. **All references contained in this bibliography are found in the NURE Bibliographic Data Base, which is available for searching on request. The services of ESIC are free to all DOE-funded researchers. All inquiries for information services should be addressed to:**

National Uranium Resource Evaluation Project
Ecological Sciences Information Center
P.O. Box X, Building 2028
Oak Ridge, Tennessee 37830
Phone: (615) 574-7765, FTS 624-7765
(615) 574-7775, FTS 624-7775

ACKNOWLEDGMENTS

F. M. Fckerson of the Grand Junction Office, Department of Energy, provided direction to the taff in defining the scope of the seven National Uranium Resource Evaluation data bases. Cathy Fore of the Ecological Sciences Information Center and the staff of the Information Sciences and Operations Department, Information Center Complex, were responsible for the computer production of this bibliography. Special thanks to A. A. Brooks of the Computer Sciences Division for his assistance in handling specific programming problems associated with the printing of this manuscript. William Chenoweth of the Grand Junction Office, DOE, supplied current information on a number of the entries. The document was reviewed for its content by Robert Floran and Mary Moran.

SAMPLE REFERENCE

A — Subject category	F — Publication description
B — Record number (of reference)	G — Publication date
C — Author	H — Abstract
D — Corporate author	I — Abstractor's initials
E — Title	J — Comments

(A) **GEOCHEMISTRY; EXPLORATION**

(B) 80

(C)(D) Page, L. R.: USGS, Washington, DC

(E) Some New Mineralogical, Geochemical and Geologic Aids in Uranium.

(F) Peaceful Uses of Atomic Energy. Proceedings of the 2nd International Conference, Geneva, September 1-13, 1958. United Nations, Vol. 2.

(G) Survey of Raw Material Sources, (pp. 123-125), 843 pp. (1958)

(H) Study of the distribution of elements and the alteration of detrital minerals in sandstones of the Slick Rock district has resulted in the recognition of the asymmetric distribution of various minerals on either side of the roll ore bodies and the relation of this distribution to the path of mineralizing solutions. One of the most useful geochemical techniques applied to understanding altered ores is the study of radioactive equilibrium. Use of the radioluxograph has aided greatly in speeding up studies of distribution of the radioactive minerals. The use of lead isotope analysis of minerals such as jarosite, limonite, and other secondary minerals is suggested as a method of indicating leaching of uranium with downward migration to unoxidized zones. Fundamental data has been contributed on the problem of leaching uranium from volcanic tuffs by groundwater and precipitation in sandstones. Isotope variations in the lead of nonradioactive minerals, such as galena or pyrite, have potential significance in prospecting for regional enrichments or local concentrations of uranium and thorium. Research on uraniferous limestones in New Mexico has isolated and identified, with synthesized materials, a uranium-bearing ester of phthalic acid, a petroleum derivative, as the organic compound which when irradiated, yields asphaltite or the thucholite-type hydrocarbons in some deposits. Stream sampling as a reconnaissance tool can narrow the area in which detailed stream and soil sampling are warranted. These are the more important advances in mineralogy, geochemistry, and geologic knowledge which have aided in the
(I) recognition and understanding of uranium deposits. (PAG)

(J) The paper is a summary based on nine other papers presented at the conference.

GEOCHEMISTRY

1
USGS, Washington, DC

Progress Report: Colorado Front Range Area. TEM-97A; 2 pp.(1951, August)

During 1949 the reconnaissance work in the Colorado Front Range included the examination of 150 primary veins, 50 pegmatites, 20 deposits in sedimentary rocks, 5 disseminated deposits, 25 metamorphic and igneous rocks, 10 placer deposits, 25 spring and mine waters, and 10 mill and mill products for radioactive materials. Some 300 samples were collected for laboratory radiometric and chemical analysis; 50 samples were examined microscopically; approximately 1000 miles of road were logged radiometrically by carborne equipment. Radiometric testing of surface and underground workings, detailed geologic mapping of selected small areas of surface and underground workings, and sampling of radioactive areas were carried out on all known radioactive deposits. Little detailed geologic mapping of the deposits has been completed and possible extensions of them are poorly known. Work indicates that the pitchblende ore shoots mined in the past were small lens-shaped bodies that were scattered through the vein structure. There is no geologic evidence that these vein structures did cut within the limits of the mines examined. (Auth)(MLB)

2
Allegre, C.J.; Groupe de Recherches Geochimiques Louis Barrabe et Institut de Physique du Globe, Faculte des Sciences de Paris, Paris, France

Behavior of U-Th-Pb Systems in the Upper Mantle and a Model of the Evolution of the Upper Mantle throughout Geologic Times. Geochemistry International 6(1):1174-1181.(1969)

An examination of the U-Th-Pb systems in the upper mantle is made utilizing a generalized version of the Concordia diagram. A continuous evolution model is derived in which the mantle acts as an open system due to continuous extractions of volcanic magmas. Consideration of data on young cogenetic volcanic suites shows that volcanogenesis generally involves fractionation of the U/Pb ratio and that the mantle has not acted as a closed system to these elements. The extraction of lead with respect to uranium appears to be higher in the source regions of alkali basalts than in the source regions of tholeiites. The model supports initial values of mu and Th/U of 8.65 and 3.7, and an age of the earth of at least 4.60 billion years. (Auth)

3
Arth, J.G.; USGS, Reston, VA

Behavior of Trace Elements During Magmatic Processes - A Summary of Theoretical Models and Their Applications. Journal of Research of the USGS 4(1):41-47.(1976, January)

Progress in understanding the behavior of trace elements during the processes that produce igneous rocks has been made possible by the parallel development of theoretical models to describe that behavior and analytical techniques that permit precise measurement of trace-element concentrations in igneous rocks and minerals. The result of this progress is that trace-element studies may now be used to place strong limits on both the degree of partial melting or fractional crystallization involved in the production of a given magma and the identity and quantity of the residual phases. A summary of quantitative trace-element theory and partition coefficient data for igneous rocks is presented. (Auth)

4
Aumento, F., and R.D. Hyndman; Dalhousie University, Department of Geology and Institute of Oceanography, Halifax, Canada

Uranium Content of the Ocean Upper Mantle. Earth and Planetary Science Letters 12:373-384.(1971)

Fission track determinations of both the whole rock contents and the distribution of uranium in individual phases were made on twenty serpentinized ultramafic rocks from two areas in the Mid-Atlantic Ridge (Hudson Geotravers and Gibbs Fracture Zone). The rocks are thought to represent uppermost oceanic upper mantle material. Whole rock uranium concentrations, varying from 0.19 to 0.70 ppm, reflect more the subsequent histories of metasomatism (serpentinization, amphibolization and rodingitization) than concentrations of the original fresh rocks. Relic minerals reveal that, unlike continental mantle equivalents, most of the uranium is homogeneously distributed in primary

orthopyroxenes (1 ppm), and to a lesser extent (0.2 ppm) in primary clinopyroxenes. Primary olivine is relatively depleted in uranium (0.03 ppm), as is primary chrome spinel (0.09 ppm). Extrapolation to pre-metasomatic conditions suggests that at the time of crystallization these ultramafic rocks had concentrations of at least 0.1 to 0.5 ppm uranium, up to an order of magnitude greater than expected. These concentrations suggest that the ultramafic rocks are unlikely to be directly genetically related to the overlying basalts and gabbros containing 0.25 ppm uranium, but are probably primary ultramafic material from which there has been no previous episode of basalt extraction. These uranium concentrations suggest that the oceanic upper mantle (plate) has quite hig.. radioactive heat production in contrast to low heat production in the continental upper mantle. The equality of oceanic and continental heat flows is explained by the data, since the total heat produced in an oceanic plate is estimated to be about equal to that of the continental crust. One can construct a model that has an isothermal, low velocity (partial melt) layer at a shallower depth under the oceans than under the continents and that has the same heat flux from below the oceanic and shield plates. Lateral convective heat transfer in the low velocity layer is not required. High radioactive heat production of the oceanic plate can explain the high heat flows measured behind trenches with downgoing slabs. (Auth)(RAF)

5

Baranov, V.I., and Du Lieh-T'ien; V.M. Lomonosov State University, Department of Geochemistry, Moscow, USSR

Geochemistry of Uranium and Thorium in the Granites of the Kyzyltau Massif (Central Kazakhstan). Geochemistry 12:1180-1191.(1961)

The Kyzyltau massif is exposed over an area of about 600 square kilometers. Leucocratic granites constitute 94 percent of the total area of the massif. These granites differ only in grain size and in the degree of development of porphyritic texture. The principal intrusive phase is composed of coarse-grained, slightly porphyritic granites. The supplementary phase is composed of medium-grained granites belonging to two generations; the first being represented by leucocratic granites and the second by alaskites. The dike granites of the third phase include fine-grained granites, aplites, and pegmatites. The most abundant of these rocks are the first generation medium-grained granites, which form about 70 percent of the total area of the massif. The fine-grained granitic dikes occupy 21 percent of the area and the coarse-grained granites of the first phase occupy 3 percent. The average uranium content of the Kyzyltau massif is 6.9 ppm, the average thorium content is 31 ppm, and the average Th/U ratio is 4.5. The uranium content shows a tendency to increase in the successive differentiates from the earlier to the later intrusive phases. Unlike the content of uranium, the thorium content decreases in the course of magmatic differentiation. There is a definite correlation between the thorium content in the rocks and the content of the accessory minerals and biotite. In the medium-grained granites, uranium content tends to decrease with decreasing fluorite content. There is also a definite relation between the content of uranium and thorium in the granites and the texture of the rocks. The content of these elements in the porphyritic granites is higher than in the equigranular or only slightly porphyritic varieties. About 67 percent of the uranium on the average, is concentrated in the accessory minerals of the granites, with the remaining 33 percent appearing in the essential minerals. Variations in this ratio are related to grain size. The finer-grained rocks, which formed from a rapidly cooling magma, captured more of the uranium in the essential minerals than did the slower cooling coarser-grained rocks, in which uranium occurs for the most part in the accessory minerals. The principal concentrators of uranium in the rocks were allanite (averaging 30 percent of the uranium in the rocks), zircon, biotite, and in a few cases uranothorite. (JMT)

6

Barbier, J., and G. Ranchin; Centre de Recherches Radiogeologiqves de Nancy, Nancy, France

Influence de l'alteration meteorique sur l'uranium a l'etat de traces dans le granite a deux micas de St-Sylvestre. Geochimica et Cosmochimica Acta 33:39-47.(1969)

In the two mica granite of the St-Sylvestre massif, the transition from fresh rock at depth to the zone of surface weathering is marked by the destruction of uraninite which contains about half of the total uranium in the rock. In general, a considerable portion of the uranium (65-70 percent) is mobilized. In the lower part of the weathered zone, even though the chemical alteration effects on the rock are weak and limited to a partial oxidation of ferrous iron, the uranium so released precipitates as autunite along cracks; but for sample sizes in

the kilogram range, the uranium content does not change. In the upper part of the zone of weathering, where the chemical alteration effects are stronger, the autunite itself is dissociated and the uranium is again released. A fraction of the uranium is removed from the surface zone and, as a result, the average content of the surface samples is appreciably less than the average content of the unaltered rock at depth. Some uranium is also redistributed in a desseminated form on the adsorptive surfaces of alteration products, so that, locally, the uranium content changes little, though it sometimes increases. In this type of granite, the distribution of the uranium in near surface rocks is essentially determined by all the processes of the weathering cycle. The results in a geochemical distribution of uranium which is very different from that encountered is unaltered rocks at depth. (Auth)

7
Barker, F.B., and R.C. Scott; USGS, Denver, CO

Uranium and Radium in Ground Water from Igneous Terranes in the Pacific Northwest. USGS Professional Paper 424-B, (pp. 298-299).(1961)

Water samples from the igneous terranes of the Northwest were collected and analyzed for U and Ra. The terranes were divided into those developed on the Idaho batholith (silicic intrusive terrane), Columbia River basalt, Snake River basalt, and silicic-subsilicic volcanic rocks. Observations indicate some general trends regarding the concentration of U and Ra to be expected in water from igneous terranes. The relative abundance in igneous rocks were generally in the order of: silicic extrusive greater than silicic intrusive which were greater than basic extrusive. The concentrations of U in the water samples were in the order of: Snake River basalt greater than silicic-subsilicic volcanic rocks which were greater than Columbia River basalt which was about equal to Idaho batholith; the concentrations of radium were in the order of: silicic-subsilicic volcanic rocks greater than Idaho batholith which was approximately equal to Snake River basalt which was greater than Columbia River basalt. The apparent disorder of concentrations of U in water with respect to the abundances of U in rocks has been attributed partly to climatological and topological factors for the Idaho batholith, and to man's agricultural developments on the Snake River Plain. (RAF)

8
Barker, J.C., and K.H. Clautice; US Bureau of Mines, Alaska Field Operations Center, Anchorage, AK

Anomalous Uranium Concentrations in Artesian Springs and Stream Sediments in the Mount Prindle Area, Alaska. OFR 130-77; PB-271 878; 19 pp.(1977)

A half-mile long series of radioactive artesian springs was found during a mineral resource study of the proposed Beaver Creek National Wild River in the Tanana Uplands. The springs are near the headwaters of Little Champion Creek along the contact of the Mount Prindle granite pluton and the Birch Creek schist. Geochemical analyses of stream sediments in this drainage basin and that of Champion Creek show anomalously high amounts of uranium. Up to 400 ppm were detected in stream sediments and analyses of spring sediments ranged from 47 to 570 ppm. No visible uranium minerals were identified. (Auth)

9
Barnes, J.W., E.J. Lang, and H.A. Potratz; Los Alamos Scientific Laboratory, Los Alamos, NM

Ratio of Ionium to Uranium in Coral Limestone. Science 124:175-176.(1956)

Samples of coral limestone cuttings taken over the first 200 ft in drilling on Elugelab Island were analyzed for uranium by the sodium fluoride fluorometric method and ionium by a radiochemical procedure. The ionium content varied with depth. Near the surface the coral contained less than 2 X 10(E-6) ppm, with increasing depth the content first increased, reached a value of 4 X 10(E-5) ppm at 100 ft, decreased sharply to about 2 X 10(E-5) ppm, and increased again, reaching a value of 4 X 10(E-5) ppm at 160 ft. The uranium content varied within much narrower limits (2.9-5.5 ppm). (RAF)

10
Baturin, G.N.; Institute of Oceanology, Academy of Sciences of the USSR, Moscow, USSR

Uranium and Sedimentation in the Black and Azov Seas. Lithology and Mineral Resources 8(5):540-549.(1974, July)

In the rivers of the Azov-Black Sea Basin, uranium migrates mostly in solution. Its distribution in Azov Sea sediments is relatively uniform. It is markedly inconsistent in Black Sea sediments where it generally duplicates the pattern of organic carbon distribution. The uranium/organic carbon ratio in Black Sea sediments increases as the rate of sedimentation decreases. At the water-sediment boundary, uranium precipitation from sea water is facilitated by the lower Eh values. Not over 15 to 20 percent of hydrogenous uranium is deposited in the halistatic reaches of the Black Sea, while the bulk of it is dispersed in the sedimentary material. In the Black Sea ooze solution uranium content reaches 65 x 10(E-6) g/liter. Conditions favorable for uranium conentration are absent in the Azov Sea which is a shallow-water circulation basin with sediments frequently stirred up by storms. (Auth)(JMT)

11
Baturin, G.N.; Institute of Oceanology, Academy of Sciences USSR, Moscow, USSR

Uranium in the Modern Marine Sedimentary Cycle. Geochemistry International 9:1031-1041. (1974, August)

The weathering of rocks and the transportation of sediments by streams are accompanied by separation of uranium into dissolved and suspended fractions with the average ratio of 1:1. The content of uranium in the two fractions corresponds, in general, to its content in the rocks of the earth's crust. In seas and oceans, the major part of dissolved uranium is precipitated with the terrigenous material. As a result, the background uranium content characteristic to all sedimentary rocks is restored in the modern sediments. The hydrogenic uranium, bringing the concentration of this element in the sediments above the background content, plays a subordinate role in the general balance of uranium. Accumulation of hydrogenic uranium in marine sediments is aided by organic matter and phosphorus, high concentration of uranium in the waters, low pH and Eh in bottom waters, slow sedimentation, and circulation of the bottom waters. Combination of all these factors is not common and the concentration of uranium in modern sediments does not exceed 10-60 ppm. Transfer of uranium from the solid phase into interstitial waters, where the concentration reaches 0.00001 to 0.0001 g/liter, is a prerequisite for its redistribution during diagenesis. (JMT)

12
Bayushkin, I.M., and Yu. P Dikov; Moscow Institute of Geological Exploration, Moscow, USSR

Uranium Silicates in Hydrothermal Uranium Mineralization. Geochemistry International 11(6):1162-1169.(1974)

It is believed that metasomatic hydrothermal uranium mineralization begins with the formation of metastable uranium silicates in strongly alkaline media, which undergo several transformations and finally form oxide-silicate uranium ores. Uranium silicates crystallize in alkaline solutions with relatively high sodium content. Besides uranous and sodium orthosilicates, silicates of sodium and uranyl (and of potassium and uranyl in solutions containing potassium) were obtained in the experiments. This indicates that the so-called secondary uranium minerals may form in the hydrothermal environment together with uranous oxide and silicates. Complex uranium silicates, analogous to such zirconium silicates as catapleite and vlasovite, form in strongly alkaline solutions. These metastable uranium compounds are not known in nature, but it is probable that they crystallize during formation of uranium-bearing albitites. As the hydrothermal solutions change from alkaline to nearly neutral the complex polymerized uranium silicates are transformed into simpler and more stable uranium orthosilicates, and these, in turn, break down into uranium hydroxides and oxides. It is possible that the nenadkevite ores in albitites were formed as a result of such transformations and represent a mixture of various intermediate products of decomposition of the hypothetical chain and ring uranium silicates. (JMT)

13
Belevtsev, Ya.N., and A.N. Komarov

Uranium in Metamorphic Rocks and Processes. CONF-7205116; Radioactive Elements in Rocks, Reports of the 1st Radiogeochemical Congress, USSR, May 15-19, 1972. Novosibirsk, Publishing House, Nauka, Siberian Branch, Novosibirsk, (pp. 133-140).(1977)

The loss of uranium during processes of regional metamorphism is associated with dehydration of the rocks and the migration of uranium by metamorphic solutions toward the lower degrees of metamorphism. In the least metamorphosed

types of heterogenous rocks, the orogenic elements form independent autigenic minerals, saturate the molecular-film solution, or they are found within the fragments of accessory ores and non-ore clastic minerals, or absorbed by non-ore minerals. When the degree of metamorphism increases, the orogenic elements are partially captured by the crystalline lattices of the newly formed minerals or form independent minerals. The latter frequently create films or fill the spaces between the rock-forming minerals. The removal of hydroxyl water from the rocks at high temperatures and pressures can cause the destruction of crystalline lattices of the newly formed hydrate minerals. This is often accompanied by dissolution and migration out of uranium. During such a transformation, only a small fraction of the uranium is preserved in the form of isomorphic impurities as a part of the accessory minerals. Geological calculations from experimental data show that uranium is intensively transported in the form of complex uranyl-sodium-carbonate ions at temperatures above 450 degrees C at pressures exceeding 500 atmospheres. Regional dynamothermal metamorphism causes the extensive migration of uranium. The migration out of uranium reaches 50 to 75 percent of the initial value at the high facies of metamorphism. The highest concentrations of uranium are seen in the metasomatites (microclinites, albitites) and are products of diafluoretic activity of the postgranitization solutions. (JMT)

14
Bell, K.G.; USGS, Washington, DC

Uranium in Carbonate Rocks. USGS Professional Paper 474-A; 29 pp.(1963)

Rocks that are composed almost wholly of carbonate minerals and that include only minute traces of other constituents generally contain about 0.0001 percent (1 gram per ton), or less, of syngenetically deposited uranium; they are among the least uraniferous rocks. The impure carbonate rocks, which form gradational series with many other kinds of sediments, may contain readily measurable quantities of syngenetically deposited uranium that is associated with the noncarbonate constituents. The quantities of such uranium may range from about 0.000X to 0.00X percent and reach a maximum of a few tens of grams per ton. The phosphatic constituent in some appreciably uraniferous limestones and dolomites is thought to hold the uranium; detrital constituents and possibly organic matter may hold uranium in other carbonate rocks. Uranium is deposited epigenetically in carbonate rocks under a variety of circumstances, and some of these deposits provide rich ores. Epigenetically deposited uranium minerals in carbonate host rocks are found in hydrothermal veins, in efflorescent deposits, in cavities of karst terrains, and as peneconcordant deposits in stratified carbonate rocks. The geochemical conditions that cause epigenetic deposition of uranium in carbonate rock environments, with the exception of those causing efflorescent deposits, have not been determined. (Auth)

Data are presented for 70 samples.

15
Berezina, L.A., and Yu.A. Bagdasarov

Stages, Zoning, and History of Radioelements in Carbonatites. Geochemistry International 5:714-721.(1968)

The behavior of uranium and thorium in a major Siberian massif and the carbonatites associated with it were examined. The massif consists of pyroxenites, pyroxene-nepheline rocks, feldspathized ijolites with alkali syenites, picrite porphyries, and carbonatites. There are four stages of carbonatites of different ages. The stage I carbonatites contain low U and Th contents. The stage II carbonatites are the main carriers of minerals that concentrate U, Th, and the rare earth elements. In the stage III carbonatites, there are three types of rocks. The first is similar to the carbonatites of stage I. The second type is hatchettolite-bearing and contain the majority of the uranium activity. The third type is pyrochlore-bearing and contains much of the thorium activity. The stage IV carbonatites are the last, low temperature products from the carbonatite process and were formed by Mg-Fe metasomatism from all earlier carbonatites. Both U and Th are lost during this stage, with the loss of U preceding that of Th. (JMT)

16
Berezina, L.A., R.V. Goleva, and E.I. Zheleznova

Content and Distribution of Uranium in Minerals from an Ultrametamorphic Complex and from Uraniferous Sodium Metasomatites. Geochemistry International 13(6):41-50.(1976)

The uranium content in the minerals of a sodium metasomatite was shown to increase regularly from the outer to the inner zones of the rocks. The degree of nonuniformity of distribution of uranium within the mineral grains increases in the same direction. In the rock-forming minerals of nonuraniferous metasomatites, the distribution of uranium is essentially uniform, but in the same minerals of uraniferous metasomatites, the distribution of uranium in the crystals is not uniform, but rather, it is concentrated in fractures, on cleavage surfaces, and in structural defects. Minerals of the uraniferous metasomatites contain introduced uranium, whose content is 30 to 50 times higher than the content of the isomorphous uranium. (Auth)(JMT)

17
Berzina, I.G., I.B. Berman, M.Yu. Gurvich, G.N. Flerov, and Yu.S. Shimelevich

Determining the Concentration of Uranium and its Manner of Distribution in Minerals and Rocks. Soviet Journal of Atomic Energy 23(1):1288-1297.(1967, July)

A method of determining the distribution and concentration of uranium in natural minerals and rocks, is discussed. The method is as follows: A nuclear particle which is released spontaneously or under bombardment leaves a defect area of track in the surrounding material which may be detected using selective chemical etching. The disturbed area is made apparent by the etching, so that is indicates the track of the nuclear particle under microscopic examination. It is then possible to differentiate between areas with different concentrations of uranium, thorium, and other radioactive elements by the magnitudes of the tracks in tens of microns. The method permits relative determinations of the concentrations of uranium and thorium in heavy mineral inclusions, as well as the "fabric" of concentration. (JMT)

18
Bimbot, R., M. Maurette, and P. Pellas; Laboratoire Joliot-Curie de Physique Nucleaire, Faculte des Sciences de Paris, Paris, France; Laboratorie de Chimie Physique, Faculte des Sciences de Paris, Centre d'Orsay, Paris, France; Laboratorie de Mineralogie du Museum d'Histoire Naturelle, Paris, France

Description d'une Nouvelle Methode Pour Mesurer le Rapport des Concentrations Atomiques du Thorium et de l'Uranium dans les Mineraux et les Verres Naturels. Application Preliminaire aux Tectites. Geochimica et Cosmochimica Acta 31:263-274. (1967)

A new method for the determination of the Th/U ratio in minerals and in natural glasses is described. This ratio was evaluated from the measurements of fission-fragment-track densities registered in the mineral after its exposure to a known flux of thermal neutrons and high energy protons (85 MeV). Applying this method to some samples of tektites, it was found that the absolute accuracy of the method is of the order of plus or minus 25 percent; however, for a relative comparison of Th/U ratios in samples irradiated simultaneously the uncertainties could be reduced to below plus or minus 5 percent. The advantages of this new method are the rapidity in the determination of the ratio and the small amount (approximately 1 mg) of material required for the analysis. (Auth)

19
Blanchard, R.L.; U.S. Department of Health, Education, and Welfare, Robert A. Taft Sanitary Engineering Center, Cincinnati, OH

Uranium 234/Uranium 238 Ratios in Coastal Marine Waters and Calcium Carbonates. Journal of Geophysical Research 70(16):4055-4061.(1965)

Water and live molluscan shell samples were collected simultaneously at seven locations on the seacoast of the United States. Samples of silt, water, and shells from an estuary were also included in the study. The water samples were analyzed for U 238, U 234, calcium, and salinity; the shell samples were analyzed for U 238, U 234, calcium, and crystal structure. All water samples, regardless of salinity or total uranium content, were found to have uranium activity ratios, U 234/U 238, within the experimental uncertainty of the 1.15 value accepted for an oceanic environment. The results indicate that the normally higher uranium activity ratio of rivers does not increase the ratio of coastal waters above the 1.15 oceanic value. The activity ratios of all except two shell samples analyzed were similar to those of the surrounding seawater and to the oceanic 1.15 value. The application of the results of the study to the determination of geologic age via uranium-uranium daughter equilibrium is discussed. (Auth)

20
Bowman, W.W.; E.I. du Pont de Nemours and Company, Savannah River Laboratory, Aiken, SC

Neutron Activation Analysis for Uranium and Associated Elements. DP-MS-77-13X; 2 pp.(1977)

Neutron activation analysis is a reliable and efficient technique for determining uranium and associated elements in the thousands of sediment and water samples arising from a hydrogeochemical reconnaissance survey. The samples obtained by the Savannah River Laboratory as part of the National Uranium Resource Evaluation Program are activated in the intense neutron flux from a Savannah River Plant production reactor. A pilot scale facility was installed at the reactor site to provide analyses of samples through the initial phase of the program and to develop design for a full-scale facility. When a sample is exposed to a neutron source, many elements absorb neutrons and are transformed (activated to radioactive isotopes, each of which has characteristic decay energies and half-life). The quantity of radioactivity induced in the element is proportional to the amount of element present in the sample, regardless of the element's chemical form. Sediments are analyzed by direct activation of 0.5 g samples. However, to analyze ground or surface water samples, mineral elements from 1 liter samples are concentrated on ion exchange resin and then 5 g samples of resin are activated. Uranium concentration is determined by counting neutrons emitted from specific short-lived products of fission induced in U 235 by the primary neutron flux. Repetitive short cycles of irradiation and counting permit detection and determination of less than 0.1 x 10(E-6)g of uranium. Elements associated with uranium are determined by spectral analysis of the gamma ray activities induced by the cyclic and subsequent longer irradiations. The pilot facility consists of four irradiation positions (plus 2 spare positions), a sample loader and unloader, and counting stations with neutron and gamma ray detectors; all interconnected with a pneumatic sample transport system. A computer controls both the transport system and the data acquistion devices. Gamma ray counting data are stored on magnetic type for further processing by a large central computer. Facility hardware and software are described. The facility has processed approximately 5,000 samples. Repetitive analyses of standards have shown an accuracy within plus or minus 10 percent for uranium values and within plus or minus 25 percent for associated elements. A quality assurance program has been developed to maintain these levels of reliability. (Auth)

21
Breger, I.A., M. Deul, and R. Meyrowitz; USGS, Washington, DC

Geochemistry and Mineralogy of a Uraniferous Subbituminous Coal. Economic Geology 50:610-624.(1955)

A sample of subbituminous uraniferous coal from the Red Desert of Wyoming was studied mineralogically. The coal contained 6 percent gypsum, one percent kaolinite, 0.3 percent quartz, and trace amounts of calcite and limonite. This suite of minerals and the absence of pyrite show that the coal was subjected to weathering and oxidation. No uranium minerals were found; mechanical fractionation indicated that the uranium is associated with the organic constituents of the coal. The isolated minerals contained 0.0006 percent uranium, a content expected for nonuraniferous sedimentary rocks. The organic components of the coal contain approximately 0.002 percent uranium. On the basis of material-balance calculations, the organic compounds carry 98 percent of the uranium in the coal. Batch extraction of the coal with 6N hydrochloric acid lead to the solution of almost 90 percent of its uranium. Recovery of the uranium is independent of the particle size of the coal between -4 and -20 mesh. It is suggested that the uranium was introduced into the coal by means of ground water carrying soluble alkaline or alkaline-earth uranyl carbonate complexes. The mineral schroeckingerite-a similar complex-is found near this subbituminous coal in the Red Desert of Wyoming. These complexes, which are unstable in acid medium, release the uranyl ion ($UO2^{++}$), which may then react with organic constituents of the coal to form ionic uranyl-organic compounds that are insoluble above a pH of about 2.2. (Auth)(MLB)

22
Brookins, D.G.; University of New Mexico, Department of Geology, Albuquerque, NM

The Grants Mineral Belt, New Mexico: Comments on the Coffinite-Uraninite Relationship, Probable Clay Mineral Reactions, and Pyrite Formation. Special Publication No. 6; 158-166 pp.(1976)

Consideration of geochemical and clay mineralogic data for some of the Grants Mineral Belt uranium deposits suggests that U+6, transported as uranyl bicarbonate ion, is precipitated as U+4 in coffinite when the activity of dissolved silica is relatively high and as uraninite otherwise. This process may take place penecontemporaneously with the oxidation of sulfur in H2S or HS- to form pyrite. Clay minerals may react with organic matter (humic acid and derivatives) such that Mg-chlorite, Mg-illite, Mg-rich mixed layer chlorite-illite or other clay minerals are also enriched in the U-rich zones. Pre-existing montmorillonite, illite, and possibly small amounts of kaolinite are influenced by the humic acid; it is postulated that Fe released is consumed during pyrite formation, Mg by clay mineral alteration/formation, Si either by new clay minerals or in coffinite. By this model no "special" solutions rich in individual ions from extrinsic sources are required. (Auth)

23

Bunker, C.M., C.A. Bush, and R.B. Forbes; USGS, Denver, CO; USGS, College, AK

Radioelement Distribution in the Basement Complex of the Yukon-Tanana Upland, Eielson Deep Test Hole, Alaska. Journal of Research of the USGS 1(6):659-663.(1973, November)

The Eielson deep test hole is about 26 miles east-southeast of Fairbanks, Alaska. The hole was drilled 9,774 feet from a collar elevation of 1,350 feet above sea level, and it is entirely within crystalline schists of the basement complex of the Yukon-Tanana Upland. Measurements of uranium, thorium, and potassium contents were determined for 94 samples of drill cuttings from the drill hole. The radioelement concentrations were determined using gamma-ray spectrometry. The rocks in the drill hole are of probable sedimentary parentage, with the exception of carbonate-free quartz-poor biotite amphibolites, which are more likely derived from the recrystallization of basic igneous rocks. The top 3,195 feet of the section is chiefly composed of calc-mica and calc-greenschists which represent recrystallized impure dolomitic limestones and marls. The interval from 4,065 to 9,198 feet contains both calc-magnesium and pelitic schists and sparse layers of micaceous quartzite. The vertical distribution of the radioelement data indicates that two types of fairly homogenous rock separate at a depth of 3,200 feet. The calcic rocks, which predominate above 3,200 feet contain significantly less uranium and slightly less thorium and potassium than the rocks in the lower section. The average uranium content in the upper 3,200 feet of the hole is 2.06 plus or minus 0.62 ppm, while in the lower section, the average uranium content is 3.52 plus or minus 0.52 ppm. (JMT)

24

Bush, W.E., and L.J. Higgins; Lucius Pitkin Incorporated, Western Uranium Project, Grand Junction, CO

Handbook of Analytical Procedures. RMO-3001, Revision 1. Supplement; 95 pp.(1965, June 17)

The handbook of analytical procedures for laboratory use contains four categories of procedures. Major and minor constituents of silicate rocks and ores; water analysis; radiochemical analysis; and uranium determinations. Procedures are given for uranium determination in dust samples, tailings, and rocks; urine samples; and water samples. Radiochemical procedures are given for analysis of alpha and beta, gross determinations in air and dust samples; polonium 210 in rocks and ore samples; radium 226 and 223 in water, rocks, and ore samples; and thorium 230 in rocks and ore samples. (PAG)

25

Cameron, A.R., and G. Leclair; Canada Geological Survey, Energy, Mines, and Resources Department, Ottawa, Ontario, Canada

Extraction of Uranium from Aqueous Solutions by Coals of Different Rank and Petrographic Composition. Canada Geological Survey Paper 74-35; 11 pp.(1975)

Laboratory tests were made to test the uranium extraction capabilities of coals of different rank and petographic composition. The samples were crushed and the -70 to +140 mesh fractions were immersed in solutions of known uranium content for a period of 32 days. Periodic checks were made to measure degree of uranium removal and pH. The results of the experiment showed differences between fusinite-rich and vitrinite-rich samples in relation to the removal of uranium from solution. These differences, however, appear to be due mainly to differences in the acidity of the

immersing solutions. Most of the uranium was removed from solution with those samples where the pH was above 5. This group included 4 of the 5 fusinite-rich samples. With samples where the pH was below 5, most of the uranium remained in solution. The fusinite-rich samples, possibly because of the leaching out of alkaline mineral matter from the organic material, tended to raise the pH of the solutions in which they were immersed, and thus brought about the removal of larger amounts of uranium. It is suggested that the mechanism of removal is by the precipitation of hydrated oxides of uranium and is, therefore, not true extraction in which the uranium becomes attached to the organic matter. (MLB)

26

Chalov, P.I., and K.I. Merkulova; Institute of Physics and Mathematics, Academy of Sciences Kirghiz SSR, Frunze, USSR

Possibility of Controlled Separation of U 234 and U 238 by External Oxidation of Uranium in Minerals. Geochemistry International 6(1):159-162.(1969)

Uranium mineral samples were held in an oxygen atmosphere for various durations of exposure and then their U 234/U 238 ratios were measured by gamma-ray spectrometry. External oxidation of uranium in minerals may change the degree of separation of U 234 and U 238 both in the valence fractions and in the aqueous extracts, but the character of this change may be different for total uranium present in a mineral and for uranium present only in microscopic dislocations. If total uranium is considered, its external oxidation may result in a decrease in the isotopic composition of uranium in the valence fractions; if uranium is separated into valence fractions and the fractions are subjected to external oxidation, the degree of separation of U 234 and U 238 will decrease. The maximum separation of these isotopes, accompanying separation of uranium into valence fractions in nature, may be ascribed to the difference in the oxidation rates of U 234 and U 238. External oxidation of uranium in microscopic dislocations may cause either an increase or a decrease in the degree of separation of uranium isotopes in the aqueous extracts from minerals. If this uranium is incompletely oxidized, external oxidation will result in a relative increase in the yield in U 234 into the extract, but only until oxidation of uranium in the structure of the mineral begins. Further oxidation will result in a decrease in the extraction of U 234. The experiments also showed that the difference in the isotopic composition of uranium in the valence fractions observed in minerals (mainly in oxides) is caused by internal oxidation of uranium by oxygen present in the mineral. External oxidation does not enrich the hexavalent fraction in U 234. (JMT)

27

Cherdyntsev, V.V., and N.I. Senina; Academy of Sciences USSR, Geological Institute, Moscow, USSR

On the Behavior of U 234 in Volcanic Processes. Geochemistry International 10(1-2):18-23.(1974, January)

In volcanic rocks, the correlation between U 234 contents and total uranium is inverse, instead of direct, as its characteristic of the supergene zone. The lowest U 234 content is found in the most radioactive effusive rocks and minerals. Almost no fractionation of uranium isotopes occurs in the young volcanic rocks at the earth's surface. Isotope fractionation is related to the mechanism of transport of uranium from the magmatic hearth. In the early stages the transporting fluids have U 234/U 238 ratios greater than one and U/Fe ratio of 10(E-6) to 10(E-7), but later U 234/U 238 becomes less than one and U/Fe = 10(E-5) to 10(E-4). (Auth.)

28

Deininger, R.W.; Rice University, Geology Department, Houston, TX

Ferrous Ion and Uranium Concentrations and Distributions in 100 Selected Limestones and Dolomites. Ph.D. Thesis; 85 pp.(1964)

Sixty-two samples were collected from the Ordovician Ellenburger Group in central Texas; seven samples were collected from the Ordovician Platteville Limestone in SW Wisconsin; and two samples were collected from the Huronian Kona Dolomite of Michigan. The distribution of ferrous iron in the Platteville and Ellenburger Dolomite suggests that iron may play a role in dolomitization. The uranium content of carbonate rocks may be controlled by the environment of deposition, the diagenetic history or both. The variations in uranium content of the rocks are attributed to differences in the calcium to uranium ratio in the medium of growth and/or

recrystallization of the carbonate minerals. The uranium content of the rocks investigated are not related directly to the carbonate mineralogy, although calcite and dolomite rocks do differ. The dolomite rocks may have more or less uranium than their more calcitic counterparts. The variations are attributed to physical or chemical variations in the dolomitizing solutions, and not to the fact that dolomitization took place. The uptake of uranium by calcite is related to the calcium to uranium ratio in the medium of crystallization, but does not appear to be related to temperature or the absolute concentration of uranium. The calcium to uranium ratio of the solutions is about 1.4 times that of the precipitates under experimental conditions. The dependence of uranium uptake upon the calcium to uranium ratio rather than uranium concentration indicates that the uranyl ion substitutes for calcium. Calcium carbonate mineralogy appears to affect the uptake of uranium, but the relationships have not been explored in the paper. Uranium does not substitute exclusively for either calcium or magnesium in these rocks. There appears to be an exception to the control of cation substitution by ionic size, electronegativity and relative abundance within the rhombohedral carbonates. In the system calcite-dolomite-magnesite, calcium substitutes more freely for magnesium than the reverse. This is attributed to the metasomatic origin of many dolomites and magnesites. (MLB)

29
Dostal, J., and S. Capedri; Dalhousie University, Department of Geology, Nova Scotia, Canada

Partition Coefficients of Uranium for Some Rock-Forming Minerals. Chemical Geology 15:285-294.(1975)

Partition coefficients of uranium between phenocrysts and their groundmass have been determined by fission-track mapping. The minerals analyzed include plagioclase, K-feldspar, biotite, olivine, clinopyroxene. The data for all these minerals show that uranium is strongly partitioned into the liquid and only a small fraction of the total whole-rock uranium content is present in the major rock-forming minerals. In volcanic rocks, the bulk of the uranium is usually contained in glass although in acid volcanic rocks, a significant portion may also be present in the uranium-rich accessory minerals. (Auth)

30
Drozdovskaya, A.A., and Yu.P. Mel'nik

Thermodynamic Analysis of the Stability of Uranium Oxides in Low-Temperature Carbonate Waters. Soviet Journal of Atomic Energy 22(1):508-509.(1967, January)

Interrelationships between anhydrate and hydrate uranium oxides and uranyl ions in low temperature carbonate waters were determined by the thermodynamic method of analysis. It was found that the basic mode of uranium migration in low-temperature waters of a hypergenetic zone at pH greater than 7 are uranyl tricarbonate complexes [UO2(CO3)3]-4. Uranyl bicarbonate complexes [UO2(CO3)3(H2O)2]-2 play an insignificant role in hypergenetic migration of uranium, and form within a very narrow pH range only when the partial pressure of CO2 is greater than 10(E-5.8) atmospheres. The stability of uranium oxides in waters of the hypergenetic zone depends on the partial pressure of CO2 to a great degree, and as a result, on the total activity of dissolved CO2 forms. As the partial pressure of CO2 increases, the activity of the uranium oxides falls off abruptly. Uranyl monocarbonate UO2CO3 (the mineral rutherfordite) can form at partial pressure of CO2 greater than or equal to 10(E+0.85) atmospheres and [U] greater than or equal to 10(E-4.84) gram-ion/liter. These conditions are very rarely encountered in nature. (JMT)

31
Edwards, K.W.; USGS, Washington, DC

Isotopic Analysis of Uranium in Natural Waters by Alpha Spectrometry. USGS Water Supply Paper 1696-F; 26 pp.(1968)

A method is described for the determination of U 234/U 238 activity ratios for uranium present in natural waters. The uranium is coprecipitated from solution with aluminum phosphate, extracted into ethyl acetate, further purified by ion exchange, and finally electroplated on a titanium disc for counting. The individual isotopes are determined by measurement of the alpha-particle energy spectrum using a high resolution low-background alpha spectrometer. Overall chemical recovery of about 90 percent and a counting efficiency of 25 percent allow analyses of water samples containing as little as 0.10 ug/l of

uranium. This procedure separates uranium from bulk impurities which add to the thickness of the final deposit causing poor resolution, and from radiochemical impurities which cause spectral interference and resultant counting errors. (Auth)(PAG)

32
Ellis, J.R.; ERDA, Grand Junction Office, Grand Junction, CO

Chemical and Physical Analyses of Selected Soil Samples in Wyoming, 1967-1969. GJBX-45(77); 320 pp.(1977, June)

The report is a compilation of field and analytical data from 310 soil samples collected in the Gas Hills, Crooks Gap, Shirley Basin, and Red Desert areas of Wyoming. Uranium was determined by gamma fluorimetry and gamma spectroscopy. Other selected elements were analyzed by standard wet methods and emission spectroscopy. Physical measurements included color and magnetic susceptibility determinations. (PAG)

This report consists of only computerized raw data.

33
Evseeva, L.S., N.P. Fomina, and G.E. Ordynets

Effect of Reducing Properties of Rocks on Localization of Hydrothermal Uranium Mineralization. Soviet Journal of Atomic Energy 25(1):971-979.(1968, July)

Reducing properties of surrounding rocks are one of the main factors of lithologic and geochemical control of uranium mineralization. In one case, the distribution of the uranium mineralization is controlled by the higher reducing capacities of the gneisses and pegmatoid granites. In the other cases, the uranium mineralization is controlled by metasomatic rocks, enriched with reducing agents in the pre-ore stage of the hydrothermal process. Despite the differences in the character of lithologic-geochemical control, in both cases the ore zones are spatially closely related with rocks with higher reducing capacities. The quantitative reducing properties of the rocks may be used as a criterion for assessing the prospects of areas under survey. (JMT)

34
Fisher, D.C., and K. Bostron; University of Miami, Institute of Marine Sciences, Miami, FL

Uranium-Rich Sediments on the East Pacific Rise. Nature 224:64-65.(1969)

The results are reported of U analyses of a series of sediments taken during a traverse across the East Pacific Rise. Most samples were from the depth interval 30 to 70 cm in the sediment cores, except for a few localities from which surface material could be obtained. Measurements were made by fission track analysis on total sediment samples. The samples were covered with Lexan plastic and reactor irradiated, the U fissions induced providing energetic fragments that impinged on the plastic and left tracks visible after etching in NaOH. Results are tabulated and shown graphically, and indicate a higher than normal U concentration at the ridges. It is considered unlikely that the U is a biogenic constituent in the sediments; the close association between high heat flow, high U content and enrichment in the crest sediments of other probably volcanogenic constituents suggests a similar volcanic origin for U. (NSA)

35
Gabelman, J.W.; Utah International, Inc., San Francisco, CA

Fundamental Sources of Uranium and Thorium. Migration of Uranium and Thorium - Exploration Significance, J.W. Gableman. The American Association of Petroleum Geologists, Tulsa, Oklahoma, (pp. 10-18), 168 pp.(1977)

The three quantitatively significant natural radioelements are, in order of decreasing abundance; potassium, thorium, and uranium. All the isotopes of thorium and uranium are radioactive, but K 40 (0.0118 percent of all K) is the only radioactive isotope of potassium. These elements have been measured extensively at the surface and interpreted from the interior of the earth by indirect evidence. The sources for this indirect evidence are: (1) Chemical and radiometric analysis of meteorites interpreted to be representative of different earth layers; (2) Estimation of values for the earth's interior from heat-flow and rock-conductivity data. These indirect methods of analysis are far from certain,

but several conclusions can be inferred from them. These are as follows: (1) Radioelements have been substantially mobilized in the primordial earth and concentrated in the crust by differentiation. (2) Each of the three elements has acted at least in part independently as indicated by the great differences in the proportions that have been concentrated. Potassium may be regarded as a potentially significant transfer agent for uranium and thorium because of their common association with it. (3) Probably more than half of all the uranium, and perhaps thorium, has been transferred to the crust. (4) The transfer process is incomplete and should still be active. (5) The transfer is global rather than local, indicated by the similarity in worldwide lithologic abundances. (6) The process of transfer and concentration into preferred rock types must be the same as, or closely associated with, processes of rock formation in the crust, because the abundance in specific rock types is so consistent. (7) The maximum concentrations of uranium and thorium in any rock type are at the parts-per-million level, whereas the concentrations in ore deposits are nearly at the percent level. This difference of three orders of magnitude suggests that concentration by rock-forming processes may be completely different from concentration by mineralizing processes. (8) Concentrations of uranium and thorium at the parts-per-million level in highly specialized primary rock types such as some carbonatites and syenites suggest that the uranium and thorium may represent the transition from rock-forming processes. (9) The tendency of thorium and uranium to follow the light silicates to the crust rather than to follow other metals to the core, is unusual considering their high density. This behavior has been attributed to their incompatibility in ordinary silicate lattices, their tendency to volatilize at lower temperatures than other core metals, and their strong tendency to combine with flourine, chlorine, and oxygen. (10) The direction of heat flow, and presumably of elemental differentiation and radioelement transfer, is nearly vertical. (11) The equality of heat flow from continents and ocean basins, together with the inequality of radioelement abundances in their respective rocks, indicates that the mantle beneath ocean basins contains a higher concentration of radioelements than does the mantle under continental crust. (JMT)

36

Gabelman, J.W.; Utah International, Inc., San Francisco, CA

Geochemistry of Uranium and Thorium. Migration of Uranium and Thorium - Exploration Significance, J.W. Gabelman - The American Association of Petroleum Geologists, Tulsa, Oklahoma, (pp. 19-21), 168 pp., 1977

Uranium has an ionic radius of 1.05 angstroms with six valence electrons. In nature, it occurs in the tetravalent and hexavalent states. Because the ionic radius of uranium is close to that of calcium and the trivalent rare earths, uranium is captured by minerals of these elements. Hexavalent uranium compounds, because of their greater ionic potential, are chemically more mobile than tetravalent uranium compounds. Uranium reacts readily with all nonmetallic elements and many metallic elements including Ba, Pb, [illegible], Ni, Mn, Co, Zn, and Be. Thorium has an ionic radius of 1.10 angstroms and four valence electrons. In nature, it occurs in the tetravalent state. As with uranium, this ion exhibits behavior similar to that of bivalent calcium, trivalent cerium, and the yttrium groups of minerals. The similarity in most of their chemical characteristics causes uranium and thorium to remain together geologically, except in regard to the hexavalent oxidation state of uranium, which is responsible for their eventual separation. Their high atomic numbers of 90 and 92 would cause these elements to fractionate into the earth's core along with iron and nickel were it not for their large ionic size. This size is incompatible with the molecular lattices formed by the common rock-forming aluminum silicates. Therefore, instead of entering into early silicate minerals during earth differentiation, uranium and thorium would tend to concentrate in the volatile phase along with other large ions including the rare earths, titanium, niobium, and zirconium. The radioelement-rich volatile phase tends to be expelled from the mantle into the crust because of its lightness as well as its volatility. Thus in outward contradiction to their high density, uranium and thorium fractionate toward the crust and therefore are truly lithophile. Magmatic and pneumatolytic processes transport most of the radioelements to the crust. In magmas and their hydrothermal derivatives, uranium and thorium remain together and terminate in the complex silicates such as allanite and gadolinite, simple silicates including zircon and thorite, multiple oxides such as euxenite, samarskite, fergusonite, pyrochlore, and microlite, or phosphates including monazite. These minerals are stable and refractory. As the temperatures of mineral formation decrease, simpler more uraniferous oxides or silicates tend to form. Uraninite is the best example; it contains thorium

through the mesothermal stage. Magmatic hydrothermal processes suggest that uranium and thorium are separated by their different preferred ranges of stability in the tetravalent state. As temperature decreases, the amount of thorium deposited decreases, while the amount of uranium increases. (JMT)

37
Gabelman, J.W.; Utah International, Inc., San Francisco, CA

Mechanisms of Uranium and Thorium Transfer to the Crust. Migration of Uranium and Thorium - Exploration Significance, J.W. Gabelman. The American Association of Petroleum Geologists, Tulsa, Oklahoma, (pp. 22-29), 168 pp.(1977)

Of the mechanisms of mantle differentiation, magma generation and differentiation are considered the most important in bringing the uniformly disseminated uranium and thorium to the shallow crustal rocks. From such rocks, these elements could be concentrated further by laterogenesis. The alkalic agpaites, and more particularly, the miaskites, are most productive in this regard. The selective fractionation of radioelement-rich volatiles, their concentration in the mantle, and their rapid transfer to the crust in diatremes, are considered important mechanisms by which fluids sufficiently enriched in uranium (and in thorium at depth) can be introduced directly into continental environments. (JMT)

38
Gabelman, J.W.; Utah International, Inc., San Francisco, CA

Migration of Mantle-Derived Uranium and Thorium within the Crust. Migration of Uranium and Thorium - Exploration Significance, J.W. Gabelman. The American Association of Petroleum Geologists, Tulsa, Oklahoma, (pp. 36-39), 168 pp.(1977)

Ultramafic, mafic, and undersaturated alkaline magmas and volatiles are the most probable media for the transportation of mantle-derived uranium and thorium to the crust. How these processes relate to migration of uranium and thorium within the crust, and how they may be possible source materials for uranium deposits are discussed in this chapter. (JMT)

39
Gabelman, J.W.; Utah International, Inc., San Francisco, CA

Cycles of Uranium and Thorium. Migration of Uranium and Thorium - Exploration Significance, J.W. Gabelman. The American Association of Petroleum Geologists, Tulsa, Oklahoma, (pp. 77-78), 168 pp.(1977)

Earth differentiation is considered to be advanced but incomplete, and to be proceeding largely through the agencies of liquid or creep convection, diffusion, and igneous intrusion. Seafloor-spreading rates up to 4.5 cm per year, when compared with the proportion of uranium believed transferred to the crust, suggest that convection velocities may be greater than the transfer rate and, therefore, that uranium and thorium in convection cells may have been recycled and a proportion bled off for transfer during each cycle. It is assumed that all crustal uranium and thorium originated from the mantle. The only lines or points of direct transfer to the crust are the oceanic spreading axes, taphrogenic faults, and points of volcanism or gas explosion. By far the greatest amount would have been fed through the spreading-axis volcanoes into the ocean crust and, in turn, fed into orogenes at continental margins. This inference is based on the fact that an overwhelmingly greater proportion of mantle material is placed in the crust by oceanic volcanism than by continental volcanism, despite the much higher radioelement abundances in continental volcanic material. In orogenes, much uranium and thorium may be recycled to the mantle down subduction planes, but a portion should be transferred into mobile-belt roots. The only mechanisms recognized for transfer into upper continental crust are deep-mantle volcanism behind or in orogenes, metamorphism and anatexis in orogene roots, granitic intrusion in orogenes, and mantle volcanism or pneumatolysis in cratonal interiors. Once in the upper sialic crust, uranium is transferred to the oceans through the erosion cycle, and eventually is recycled into orogene roots. Separation of uranium and thorium occurs mostly during the orogenic-magmatic cycle, and less so during taphrogenic hydrothermal activity. It is believed that uranium can be concentrated during any of these processes. (JMT)

40
Gabelman, J.W.; Utah International, Inc., San Francisco, CA

Oceanic Migration History of Uranium and Thorium. Migration of Uranium and Thorium - Exploration Significance, J.W. Gabelman. The American Association of Petroleum Geologists, Tulsa, Oklahoma, (pp. 79-81), 168 pp.(1977)

Most ophiolite is returned to the mantle via subduction zones, possibly carrying most of its uranium and thorium with it. Further differentiation of oceanic crust into continental sial must occur in the orogenes at converging plate margins, which usually coin ide with continental margins. The western North American orogene originally was beneath the Cordilleran mobile belt, but it probably shifted eastward to beneath the Rocky Mountains when the continent overrode the Pacific spreading axis. With orogenic differentiation, descending ophiolite would be enriched in ultramafic constituents and some of the sialic constituents would be added to the orogene root, where granitic bodies are formed through regional metamorphism and anatexis. Once isolated, these bodies of relatively pure granite would begin to rise because of their low density. They would melt and intrude the crust as sialic magmas. Probably most of the uranium and thorium which enter the crust are added by this mechanism. (JMT)

41
Gabelman, J.W.; Utah International, Inc., San Francisco, CA

Orogenic Continental-Margin Histroy. Migration of Uranium and Thorium - Exploration Significance, J.W. Gabelman. The American Association of Petroleum Geologists, Tulsa, Oklahoma, (pp. 82-114), 168 pp.(1977)

The orogenic continental margin history and how it applies to uranium and thorium migration within the earth is dicussed. The subduction zone, island arcs, the orogene root zone, the orogenic foreland margin, are detailed along with the geologic processes associated with them. (JMT)

42
Gent, C.A.; USGS, Denver, CO

Preparation of Pyrite-Coated Sand Grains for Research on Roll-Type Uranium Deposits. Journal of Research of the USGS 5(5):595-596.(1977, September)

Ordinary quartz sand grains can be coated with pyrite for use in laboratory experiments on the genetic geochemistry of roll-type uranium deposits. The sand is first added to a ferric chloride solution. The slow addition of sodium hydroxide to the mixture gives the sand grains an iron oxide coating. This coating is then converted to pyrite by reaction with hydrogen sulfide, thus a product suitable for exprimental use. (Auth)

43
Gentry, R.V., W.H. Christie, D.H. Smith, J.F. Emery, S.A. Reynolds, R. Walker, S.S. Cristy, and P.A. Gentry; Oak Ridge National Laboratory, Chemistry Division, Oak Ridge, TN; Oak Ridge National Laboratory, Analytical Chemistry Division, Oak Ridge, TN; Oak Ridge National Laboratory, Y-12 Plant, Laboratory Development Division, Oak Ridge, TN; Columbia Union College, Takoma Park, MD

Radiohalos in Coalified Wood: New Evidence Relating to the Time of Uranium Introduction and Coalification. Science 194(4262):315-318.(1976, October)

The discovery of embryonic halos around uranium-rich sites that exhibit very high U 238/Pb 206 ratios suggests that uranium introduction may have occurred far more recently than previously supposed. The discovery of Po 210 halos derived from uranium daughters, some elliptical in shape, further suggests that uranium-daughter infiltration occurred prior to coalification when the radionuclide transport rate was relatively high and the matrix still plastically deformable. (Auth)

44
Gladkikh, V.S., and A.A. Lebedev-Zinov'yev; Institute of Mineralogy, Geochemistry and Crystal Chemistry of Rare Elements, Moscow, USSR

Uranium and Thorium in the Alkali Olivine Basalt Series. Geochemistry International 8(6):813-820.(1971)

The distribution of uranium and thorium was determined in 158 samples of lavas belonging to the alkali olivine basalt series of the Maymecha-Kotuy and Kuznetsk-Alatau provinces and the graben zone of the southern part of the Russian platform. Uranium was determined by the luminescence method and thorium was

determined by spectrophotometry. It was found that both uranium and thorium, along with zirconium and niobium, accumulate in the rocks of the alkali olivine basalt series with increases in the alkali content, from basalt to the alkalic differentiates (trachyandesites and trachytes). The Th/U ratio decreases in the same direction. The highest uranium and thorium concentrations are found in the differentiates of the alkali olivine basalt magma with the highest sodium and potassium contents. (JMT)

45
Gluskoter, H.J., R.R. Ruch, W.G. Miller, R.A. Cahill, G.G. Dreber, and J.K. Kuhn; Illinois State Geological Survey, Urbana, IL

Trace Elements in Coal: Occurrence and Distribution. Illinois State Geological Survey Circular 499; 154 pp.(1977)

Chemical analyses of 172 whole coal samples, 40 bench samples, and 64 washed coal samples were performed to determine concentrations of 60 elements. One hundred fourteen of the 172 whole coal samples were from the Illinois Basin, and the remaining samples were from the Appalachian coal fields and the western U.S. The analytical values for uranium in coal were: Illinois Basin Coal Fields-arithmetic mean 1.5 ppm, geometric mean 1.3 ppm, minimum 0.31, maximum 4.6, standard deviation 0.93; Appalachian Coal Fields-arithmetic mean 1.5 ppm, geometric mean 1.3 ppm, minimum 0.40, maximum 2.9, standard deviation 0.73; and Western U.S. Coal Fields-arithmetic mean 1.2 ppm, geometric mean 0.99 ppm, minimum 0.30, maximum 2.5, standard deviation 0.65. (PAG)

46
Gorobets, B.S., and G.A. Sidorenko;

Luminescence of Secondary Uranium Minerals at Low Temperatures. Soviet Journal of Atomic Energy 36(1):5-12.(1974, July)

Because all uranium minerals are important indicators of uranium mineralization, numerous secondary uranium minerals, in which uranium is present in the form of uranyl ions (UO2+2), must be isolated and recognized in the search for uranium ore. This article deals with the luminescence spectra of the uranyl mineral group at 77 degrees K and 298 degrees K. The luminescence spectra were recorded with an ISP-51 spectrograph which was equipped with a photoelectric FEP-1 attachment, an FEU-38 photomultiplier, and an EPP-09mA recording potentiometer. A test tube, which was made of quartz glass and contained a mineral sample of 5 mg or more, was placed into a transparent Dewar vessel containing liquid nitrogen. Luminescence of the mineral was excited with the light of an SVD-120A mercury-filled quartz lamp. A UFS-2 filter and a layer of 10 percent CuSO4 solution were used to single out the excitation interval ranging from 40,000 1/cm to 25,000 1/cm. The accuracy of the freqency measurements and the luminescence spectrum amounted to 10-20 1/cm in the interval 20,000-16,000 1/cm. The results of the study are detailed in the article. (JMT)

47
Grandstaff, D.E.; Temple University, Department of Geology, Philadelphia, PA

A Kinetic Study of the Dissolution of Uraninite. Economic Geology 71(8):1493-1505. (1976, December)

Oxidation of UO2, U3O8, pitchblende, and uraniferous ore material has been studied by a number of investigators. UO2 is oxidized to UO2.3-UO2.4 at temperatures up to 250 degrees C. Over 250 degrees C, the UO2.3-UO2.4 is further oxidized to U3O8. Oxidation beyond U3O8 is more difficult in the laboratory. In the presence of water the oxidation of uranium ores proceeds in a completely different manner. A surface layer is oxidized directly to UO3 or to a uranyl hydrate. At low pH this oxidized layer may be taken into solution as a uranyl ion, UO2+2. At intermediate and high pH in the presence of carbonate, the oxidized layer may react with aqueous carbonate species to produce a uranyl carbonate complex in solution. Depending on the pH conditions, either UO2(CO3)2(H2O)2-2 or UO2(CO3)3-4 is formed. Removal of the oxidized layer permits further oxidation of the solid. The oxidation of UO2 at intermediate pH in the presence of dissolved carbonate probably takes place according to the overall formula: UO2 + 1/2O2 + 2HCO3- + H2O = UO2(CO3)2(H2O)2-2. The kinetics of uraninite dissolution in water may be summarized by the equation: R=d(uran)/dt = 10(E=-0.25)[SS][RF(E=-1)] [10(E=-3.38-10.8 NOC)] [a*CO2] [D.O.] [aH+] exp [-7045/T]day(E=-1), where R is the rate of the dissolution reaction, SS is the specific surface area [cm(E=2)-gm(E=-1)], RF is an organic retardation factor, NOC is the mole fraction of nonuranium cations in the uraninite, D.O. is the dissolved

oxygen content of the water (ppm), *CO2 is the total dissolved carbonate, and T is the absolute temperature. Application of these data may allow better understanding of factors influencing oxidation of uraninite and the resulting mobility of uranium in natural waters. (JMT)

48
Habashi, F.; Montana College of Mineral Science and Technology, Department of Metallurgy, Butte, MT

Radioactivity in Phosphate Rock. Economic Geology 61(2):402-405.(1966, March)

Ten gram samples of phosphate rock from different localities were analyzed by gamma scintillation spectrometry for activity, uranium content, and potassium content. Plots of the uranium content against total gamma activity indicate that in sedimentary phosphates, uranium exists in radioactive equilibrium with its decay products. Therefore, the total gamma activity of a sample may be taken as a direct measure of its uranium content. (PAG)

49
Hamilton, E.I.; Oxford, Geology and Mineralogy Department, England, United Kingdom

The Determination of Uranium in Rocks and Minerals by the Delayed Neutron Method. Earth and Planetary Science Letters 1:77-81.(1966)

As the distribution of uranium in geological materials is so heterogenous, samples were ground to a grade of 400 mesh and an aliquot removed by inserting a plastic tube into the powder. The concentration of uranium in the samples was determined by the standard addition method with a precision of plus or minus 5 percent expressed as the relative standard deviation. Although the detection limit was quite adequate for the samples investigated, this can be increased by using larger sample weights, longer periods of irradiation, and a more efficient neutron counter. In this work approximately 16.8 micrograms of uranium using a BF3 counter of 5 percent efficiency gave approximately 6500 neutrons over a counting period of one minute. The uranium content of a few of the common accessory minerals is given. Preliminary experiments show that the delayed neutron method is suitable for the rapid determination of uranium for the measurement of U/Pb ages, although precautions must be taken to correct for any interference from thorium. (MLB)

50
Hansel, J.M., and C.J. Martell; Los Alamos Scientific Laboratory, University of California, Los Alamos, NM

Automated Energy-Dispersive X-Ray Determination of Trace Elements in Stream Sediments. GJBX-52(77); LA-6869-MS; 8 pp.(1977, June)

Nickel, copper, tungsten, lead, bismuth, niobium, silver, cadmium, and tin are determined in stream sediments using a computer-controlled energy-dispersive x-ray fluoresence system. The system consists of an automatic 20-position sampler changer, a silicon lithium-drifted detector, a pulsed molybdenum transmission-targe x-ray tube, a multichannel analyzer, and a minicomputer. Samples are analyzed as minus 325-mesh powders. A computer program positions the samples, unfolds overlapping peaks, determines peak intensities for each element, and calculates the ratio of the intensity of each peak to that of the molybdenum Ka Compton peak. Concentrations of each element are then calculated using equations obtained by analyzing prepared standards. Detection limits range from 5 ppm for silver, cadmium, lead, and bismuth to 20 ppm for niobium. The relative standard is 10 percent or less at the 100-ppm level and 20 percent at the 20-ppm level. Samples can be analyzed at the rate of sixty per day. (Auth)

51
Hansen, R.O.; University of California, Geology Department, Berkeley, CA

Isotopic Distribution of Uranium and Thorium in Soils Weathered from Granite and Alluvium. Ph.D. Thesis; 126 pp.(1965)

Primary soils weathered from granite were studied to determine the redistribution of naturally occurring uranium and thorium nuclides resulting from soil formation. Samples were taken from very shallow soils near Yosemite Valley to the San Joaquin foothills east of Fresno, California. Alluvial soils were also studied because the parent material represents mixtures of former soil fractions. Uranium and thorium were chemically separated from each sample and electrodeposited onto platinum planchets for spectrographic

measurements. In older residual soils of the Sierra Nevadas it was found that both uranium and thorium were concentrated to a greater degree than in the underlying rocks. Uranium concentrated more than thorium in the topsoils, suggesting a higher mobility of thorium with the soil surface. Both uranium and thorium were most highly concentrated in the clay fractions, with concentrations of uranium being as much as ten times greater in clays than in the underlying rocks. Uranium and thorium of the clays exist in sorbed states and are firmly fixed, presumably within the crystal lattice structures of clays. Both uranium and thorium are lost from soils by leaching, but neutral or calcareous soils lose uranium more rapidly than thorium. (PAG)

52
Hansen, R.O., and G.L. Huntington; University of California, Kearney Foundation of Soil Science, Davis, CA; University of California, Soils and Plant Nutrition Department, Davis, CA

Thorium Movements in Morainal Soils of the High Sierra, California. Soil Science 108(4):257-265.(1969)

Thorium distributions in a sequence of morainal soils in Bench Valley, California, were determined by gamma-ray spectrometry of profile simples. Concentrations of thorium ranged from 10.8 ppm. in a B2h horizon, to 24.0 ppm. in a B2ir horizon. The data indicate distinct thorium accumulation in horizons immediately underlying horizons of high organic content. A2 or B2ir horizons respectively contained higher thorium concentrations when overlain by A1 or B2h horizons. Soil organic matter apparently complexed with thorium as well as with iron, although the leached iron accumulated visibly in horizons of pH 5.5 or greater, whereas thorium distributions were more diffuse and apparently less affected by change in pH. Radium was distributed (0.85-1.91 pico-grams/g) more irregularly than was thorium, reflecting the effects of the soil chemistry of U 238, U 234, Th 230, as well as Ra 226, with the passage of time. Radium distributions are explained in terms of uranium retention by organic matter, mobilization of Th 230 by organic matter, plant absorption of radium, and time. Potassium concentrations ranged from 1.9 per cent to 4.8 per cent, being generally higher in A2 horizons than in A1 horizons. (MLB)

53
Heier, K.S., and K. Thoresen
Mineralogisk-Geologisk Museum, Oslo, Norway

Geochemistry of High Grade Metamorphic Rocks, Lofoten-Vesteralen, North Norway. Geochemica et Cosmochimica Acta 35:89-99.(1971)

Ninety-one samples of granulite and amphibolite facies rocks were analyzed for the major elements and the trace elements Rb, Sr, Ba, Zr, Pb, Th and U. Rock units in the amphibolite and granulite facies with comparable range in major element chemistries are significantly different in trace element contents. The granulite facies rocks are characterized by low Rb, Th, and U concentrations. Their Pb concentrations are also significantly lower than in comparable amphibolite facies rocks. Subsequent retrograde metamorphism does not noticeably affect the trace element concentration of the rocks. (Auth)

54
Hills, J.H., and J.R. Richards

Pitchblende and Galena Ages in the Alligator Rivers Region, Northern Territory, Australia. Mineral Deposits 11(2):133-154.(1976)

Uranium-lead and lead isotopic studies were made of pitchblendes and associated galenas from four major deposits in the Alligator Rivers region of the Northern Territory, Australia. These were compared with previously-published data on deposits in the South Alligator Valley and in the Westmoreland area on the Queensland border. In all, four different times of possible mineral formation were detected: 1880 m.y.; 1700 m.y.; 800-900 m.y.; and 400-500 m.y. Some deposits gave only one time, others two; no deposit showed evidence of all four. The associated galenas are in general highly radiogenic; some of which can be interpreted as reflecting development in two completely different generations of pitchblende. The clearest evidence for solid-state formation of galena from presently existing pitchblende is to be found at Nabarlek, where the major time of pitchblende formation (920 m.y.) showed no relation to any known Rb-Sr or K-Ar age. (Auth)(JMT)

55
Hutta, J.J., and H.D. Wright; National Lead Company, Titanium Division, South Amboy, NJ; The Pennsylvania State University, Geochemistry and Mineralogy Department, University Park, PA

The Incorporation of Uranium and Silver by Hydrothermally Synthesized Galena. Economic Geology 59:1003-1024.(1964)

Crystals of galena were grown hydrothermally in the presence of uranium over a range of temperatures at constant pressure. Uranium concentration in the resulting crystals was determined radiometrically, and the distribution of uranium was studied by means of autoradiographs. It was found that appreciable amounts of uranium are incorporated by galena crystals during their growth, the amount being dependent on the temperature of crystallization. On the other hand, previously crystallized galena subjected to uranium-bearing hydrothermal solutions takes up uranium only in cleavages; solid diffusion is negligble within the time limits of experimentation. In natural samples, this feature may serve to differentiate introduced uranium from that incorporated during crystallization. The amount of uranium incorporated ranged from 900 ppm at 215 degrees C to less than 100 ppm at 500 degrees C. The inverse temperature relationship suggests that uranium is not present in solid solution. Autoradiographs of low temperature specimens are characterized by radial clusters of many alpha tracks, and the high temperature specimens by only a few single tracks per crystal. Calculations on the observed distribution of alpha tracks indicate that the upper size limit of uranium oxide particles producing single tracks is well below one micron. Particles large enough to produce the clusters of tracks observed in the low temperature specimens range to several microns, suggesting that the uranium was incorporated by adsorption. (Auth)(MLB)

56
James, G.W., and L.R. Hathaway; Kansas Geological Survey, Lawrence, KS

Recent Advances in Analytical Methods for Determining Uranium in Natural Waters and Geological Samples. CONF-760316; IAEA-SM-208/28; Exploration of Uranium Ore Deposits, Proceedings of a Symposium, Vienna, March 29-April 2, 1976. International Atomic Energy Agency, Vienna, (pp. 311-320), 807 pp.(1976)

Recent advances in the design of X-ray emission (fluorescence) spectrometers have made possible the direct and rapid determination of low levels of uranium in sediments, soils, and various rock types. When combined with simple resin concentration techniques, procedures utilizing this instrumentation also allow the rapid determination of nanogram amounts of uranium is surface waters, ground-waters, and acid-leach solutions of geological samples. Detection limits and relative precision are a function of X-ray instrumentation, analytical counting time, and sample preparation, and these may be varied to fit the criteria dictated by different programmes strategies. Routine detection limits of 2 ppm for 2-g rock samples, and of less than 0.5 microgram per litre for 250 ml of natural waters are easily obtained. In addition to allowing the rapid determination of uranium at low levels in various types of samples, modern X-ray emission spectrometers can be fully automated to handle both single or multi-element analyses in either exploration programmes or ore-grade quality control programmes at the rate of hundreds of samples per week. (Auth)

57
Komarov, A.N., and N.V. Skovordkin; Institute of Precambrian Geology and Geochronology, Academy of Sciences USSR. Leningrad, USSR

Investigations of the Abundance and Distribution of Uranium in Ultramafic and Mafic Rocks by Fission Track Methods. Geochemistry International 6(1):127-133.(1969)

The uranium contents of ultramafic rocks from the Kola peninsula was investigated by fission track analysis. Most of the samples were unaltered, but some showed signs of alteration, and many were taken from considerable depth to exclude the effect of infiltration of uranium from the supergene zone. The lowest concentrations of uranium were found in the olivinites of the Monchegora pluton [0.001-0.0046 ppm]. The peridotites and pyroxenites have higher uranium contents [0.0098-0.0156 ppm] with a considerable number of the fission tracks forming local groupings associated with an unidentified accessory mineral occurring in minute grains up to 0.01 mm in diameter. This mineral averaged about 100 ppm uranium and was sparsely distributed in the rocks. The unaltered norite contained 0.057 ppm uranium, with much of it (78 percent) localized in illmenite occurring between the grains of other minerals. The uranium content of the gabbroid rocks ranged from 0.0068-0.028 ppm, and was

higher in the altered samples. Not more than 30 percent of the uranium was localized in isolated areas, and no relation between these areas and segregations of accessory minerals could be established. The content of uranium in the altered rocks was considerably higher. In altered norite, containing secondary quartz, biotite, hornblende, scapolite, zircon, and sphene, the uranium concentration reached 0.46 ppm. Some samples of regionally metamorphosed gabbro containing hornblende replacing pyroxene also had relatively high uranium concentrations, reaching a maximum in the strongly altered areas composed of garnet and biotite with inclusions of rutile. In these areas uranium occurred in the dispersed form and in minute crystals of sphene and zircon containing 80-200 ppm uranium. In all the rocks investigated, enrichment of uranium is related to the latest, autometamorphic, stages of their formation, and especially to the superimposed processes. The low total uranium contents in the unaltered rocks of the Monchegora pluton are a result of the capture of small amounts of uranium by the minerals during the early stages of crystallization of the mafic magma. (JMT)

58
Komarov, A.N., A.S. Zhitkov, L.V. Dmitriyev, and L.L. Leonova

Uranium Distribution in Ultrabasics of Indian Ocean Rift Zones. Geochemistry International 10(1-2):217-221.(1974, January)

Uranium contents in peridotites from the Carlsberg and West Indian Ocean areas were examined by fission track radiography. High uranium concentrations occur in veinlets and hydrothermally altered zones where there were grains of apatite and a mineral of sphene type. The results of the experiment showed that there was considerable influx of uranium after the rock was formed: a) the low uranium level in the pyroxene and the high uranium level in the serpentine replacing it; b) there were elevated amounts of uranium in veinlets and ferruginous parts, which were unevenly distributed. (JMT)

59
Kozlov, A.A.; All-Union Institute of Nuclear Geophysics and Geochemistry, Moscow, USSR

On the Distribution of Uranium in the Phosphorites of the Russian Platform. Geochemistry International 12(2):136-138.(1975)

Distribution of uranium was investigated in the nodular phosphorites of the central regions of the Russian platform, in the bedded phosphorites of the Khopersk zone, and in the bone detritus fossil reptiles and phosphate pseudomorphs after organic remains. The phosphate of the phosphorite nodules is kurskite with uranium contents ranging from 22 ppm to 32 ppm in different deposits. The highest uranium contents (40-50 ppm) are localized in the amorphous phosphate most intensively colored by humic matter. This was observed in the fecal pellets of mud burrowers, in the bones of fossil reptiles, and the bone cavities filled with phosphate that had been colored dark redish-brown by organic matter. The distribution of uranium in phosphates is dependent on the structures of the bones. In the crystallization of bone phosphate to holocrystalline material, uranium is removed and its content decreases to an average of 0.2 ppm. (JMT)

60
Kravchenko, S.M., Ye.I. Saytsev, and Ye.V. Shatagina; Institute of Mineralogy, Geochemistry and Crystal Chemistry of Rare Elements, Moscow, USSR

Uranium as an Indicator of Magmatic Processes of Formation of Differentiated Intrusives (with Lovozero Pluton as an Example). Doklady Akademii Nauk SSSR 218(1-6):215-218.(1975, November)

The tabular Lovozero intrusive is about 25 km in diameter, and is composed of regularly alternating varieties of nepheline syenite and a mushroom-like body of eudialite lujavrite. The microfractionation of the uranium in the rock fabric is particularly well-defined in foyaite, which crystallized over the largest temperature interval. By far the greatest bulk of uranium was precipitated in the late derivatives, including the epimagmatic fractions. In foyaite, the peripheral parts of the loparite crystals are enriched in uranium. Typically, natrolite veinlets enriched in uranium branch off from the loparite crystals, indicating epimagmatic enrichment of the outer zones of loparite crystals in uranium. During the first-order fractionation of uranium its concentrations in the rocks did not change uniformly, a fact indicated by its average concentration in urtite, foyaite, and lujavrite (9, 21, and 43 ppm, respectively). Because the differentiated complex crystallized from the base upwards, the uranium content tended to increase from the lower to higher rhythms. (JMT)

61
Kronfeld, J.; Rice University, Department of Geology, Houston, TX

U 234/U 238 Disequilibrium in Groundwaters of Central Texas: A Progress Report on Research Completed. GJO-935-1, Part 2; Nuclear Techniques in Geology and Geochemistry, (pp. 303-310), 327 pp.(1971)

Samples of ground and surface waters from central Texas were analyzed for U content and U 234/U 238 ratio. The analysis method and results are presented. Surface U concentrations and isotopic ratios contrasted markedly with subsurface values. In general, surface U concentrations were higher than subsurface and were much closer to isotopic equilibrium. Lake Waco water samples had a U 234/U 238 ratio of 1.2 and a U content of 0.66 ppm while ground water from beneath the city of Waco had a ratio of 5.6 and U content of 0.07 ppm. Surface waters exhibited between 15 and 40 percent excess U 234. The ground water samples exhibited between 250 and 1300 percent relative enrichment of U 234. The factors governing the extreme fractionation were not established. (NSA)

62
Kronfeld, J.; Rice University, Geology Department, Houston, TX

Hydrologic Investigations and the Significance of U 234/U 238 Disequilibrium in the Ground Water in Central Texas. Ph.D. Thesis; 75 pp.(1972)

Within central Texas there exists two distinct water bodies that can be differentiated upon the basis of their uranium concentrations and isotopic compositions. Surface waters have relatively low U 234/U 238 activity ratios and generally higher uranium concentrations. The deep subsurface waters exhibit extremely high U 234/U 238 ratios and low uranium concentrations. Future work should expand the uses of U 234/U 238 fractionations as a neutral tracer. This "environmental isotope" offers two advantages as a tool for hydrologic investigations. First, as it occurs naturally, it is of so low an activity as to offer no problems of health or safety. Secondly, it is possible to make much larger scale investigations, studying processes that act over a longer time span than it is possible to do using injected radioisotopes. (Auth)(MLB)

63
Kyuregyan, T.N., and A.G. Kocharyan

Migration Forms of Uranium in Carbonate Waters of a Caucasian District. International Geology Reviews 11(10):1087-1089.(1969)

The migration forms of uranium in principal types of carbonate waters were determined by thermodynamic calculations. A correlation between the dissolved uranium and the dissolved carbon dioxide was established. The analytically determined concentrations of uranium in the waters are the sum total of U in all the uranyl complexes which coexist at a given time in the given water. The calculation's formula include compounds of hexavalent uranium only, because of the oxidation environments of the waters examined. The di-aqua-dicarbonate and the tricarbonate uranyls are the dominant forms of uranium in the carbonate waters and their concentrations depend upon the alkaline-acid conditions, the total dissolved salts, and the total uranium in the solution. (PAG)

64
Lewis, D.M.; Yale University, New Haven, CT

The Geochemistry of Manganese, Iron, Uranium, Lead-210 and Major Ions in the Susquehanna River. Ph.D. Thesis; 272 pp.(1976)

Streams which drain a single general rock type have a constant concentration (plus or minus 10 percent) of dissolved ions while discharge may vary by two orders of magnitude. The change in composition accompanying a change in discharge of large streams and the Susquehanna River results from the change in the proportions of the total flow composed of type waters of constant composition. This change in the flow proportions is due to the different hydrologic responses to precipitation inputs of basins underlain by different single rock types. The in-river precipitation of mine-drainage-injected Mn and Fe was studied at a pH of approximately 7. For Mn the removal from solution appears to be first order. The rate constant is 10(E+3) times greater than the extrapolated autocatalytic rate constant of previous laboratory experiments. Mine-drainage-injected Pb 210 has been used to study trace metal removal kinetics in the river. At a pH of approximately 7 the removal of Pb 210 from solution has a first order half time of less than one day. The Mn, Fe, and Pb 210 data show that there is no pronounced natural seasonal

variation in the concentration of dissolved trace metals. The Mn data indicate that mine drainage dominates the variation of Mn seen at the river mouth. The amount of dissolved U 238 in streams is related to the amount of rock weathered. Conversely, the U 234 in solution is dependent on the residence time of the stream water as ground water. The U 234/U 238 activity ratio of dissolved U is due to a combination of the above phenomena. The dissolved and particulate U data show that U is removed from solution onto the suspended sediment in the Susquehanna. This process may be a natural phenomenon and would contribute to the soluble U delivered to the oceans. (MLB)

65
Ludwig, K.R.; USGS, Denver, CO

Uranium-Daughter Migration and U/Pb Isotope Apparent Ages of Uranium Ores, Shirley Basin, Wyoming. Economic Geology 73(1):29-49.(1978, January)

Migration of uranium daughters has greatly affected the U/Pb isotope ages of the Tertiary uranium ores and constituent minerals sampled from three mines and three ore types in the Shirley Basin, Wyoming. U/Pb ages of pitchblende grains are typically low, showing moderate to extreme normal discordance, and they are very sensitive to the presence of pyrite impurities. Pyrite separates give typically high U/Pb ages, ranging in discordance from moderate-normal to moderate-reverse. Total ore samples give U/Pb ages intermediate between pitchblende and pyrite and are slightly to moderately discordant. The observed apparent age ranges for the pitchblende was 6-30 m.y. using the Pb 206/U 238 method; 14-35 m.y. by the Pb 207/U 235 method; and 270-2,400 m.y. using the Pb 207/Pb 206 method. Other key findings are that all pyrite separates from ores contained 130 to 620 ppm unsupported radiogenic lead, and a separate of coalified wood from an ore contained 800 ppm of unsupported radiogenic lead having a Pb 207/Pb 206 value of 0.012(-5,850 m.y. using the Pb 207/Pb 206 method). These U-Pb isotope systematics are the result of the loss of both lead and radioactive daughters of U 238 from pitchblende and the subsequent migration of these uranium daughters. Migrating lead was both lost from the total ore and incorporated by pyrite, whereas migrating radioactive daughters were both lost from the total ore and trapped by material such as coalified wood. If young uranium ores such as the Shirley Basin ores have experienced neither uranium migration nor a net gain of extraneous uranium daughters, then geochronometry is possible even though the ores have lost lead. Even some ores open to both lead and radioactive daughter loss can be dated if the time-average leakage of radioactive daughters can be estimated. The main requirement of such open system dating is that the isotopic composition of the lead lost by the total ore be similar to that of the lead gained by the pyrite. The time of pitchblende formation in the Shirley Basin for the youngest ore sample analyzed is inferred to be 24 plus or minus 3 m.y. ago, whereas the oldest sample was apparently formed before 35 m.y. ago. These limits require source rocks for the uranium in the Shirley Basin orebodies to have existed from at least early Oligocene time. (Auth)(JMT)

66
Ludwig, K.R., B.J. Szabo, and H.C. Granger, USGS, Denver, CO

Pleistocene Apparent Ages by U-Pb Isotope and U-Series Methods for Uranium Ore in Dakota Sandstone Near Gallup, New Mexico. Journal of Research of the USGS 5(6):669-672.(1977, November)

A uraninite-pyrite-rich sample was collected from a low-grade ore pile at Hogback No. 4 mine near Gallup, New Mexico and then analyzed radiometrically. The uranium-series dating method gave apparent ages, though discordant, to indicate a late Pleistocene age of uranium mineralization. The Th-230 and Pa-231 ages of 130,000 and 78,000 years, respectively, may be considered as minimum ages, whereas the open-system-model age of 160,000 years may be considered a maximum age. Pb-206 and Pb-207 apparent ages of 70,000 and 100,000 years, respectively are in broad agreement with the uranium-series dates. (JMT)

67
Mel'gunov, S.V., A.S. Mitropol'skii, and N.A. Kulik

Uranium and Thorium in the Process of Formation of Rocks of the Zonal Metamorphic Complexes. CONF-7205116; Radioactive Elements in Rocks, Reports of the 1st Radiogeochemical Congress, USSR, May 15-19, 1972. Novosibirsk, Publishing House, Nauka, Siberian Branch, Novosibirsk, (pp. 146-151).(1975)

Two zonal metamorphic complexes, chosen for their chemical and lithological uniformity, were studied in order to ascertain the role of metamorphism in the behavior of uranium and thorium. A comparison of the average contents of uranium and thorium showed the relationship of the change in concentration of these elements with the degree and character of the metamorphism. Migmatites of the complex contained 9 times less uranium and 3 times less thorium than the weakly metamorphosed rocks of the complex. The granitoids of the complex are enriched in uranium and thorium, having 3 to 6 times the uranium and 2 times the thorium of gneisses and migmatites in the complex. A sharp decrease in the amount of uranium, amounting to about 60 percent of the initial content, is associated with the transformation of rocks under conditions of biotite sub-facies of the greenschist facies and the low temperature stage of the epidote-amphibolite facies. The extraction of thorium from the rocks occurs during the formation of migmatites. The redistribution of uranium and thorium in the Kuraisk complex is somewhat different. Here, as in the Chuisk complex, the metapelites lose uranium with the strengthening of metamorphism, but in the metabasites of the greenschist and epidote-amphibolite facies, the average amounts of uranium do not change, and only at the initial stage of the amphibolite facies is the transport of uranium found. The content of thorium for the crystalline shales and gneisses of the complex is unaffected by the later changes and the thorium content remains practically constant. (JMT)

68
Miholic, S.

Secondary Enrichment of Uranium in Sediments. International Geological Congress, Proceedings of a Conference, Copenhagen, Denmark, 1960. Part 15, Genetic Problems of Uranium and Thorium Deposits, (pp. 73-77), 164 pp.(1960)

Drilling operations at the thermal springs of Fojnica and the fofettes in Klokoti have added new information on the mechanism of the secondary enrichment of uranium in sediments from mineral waters. In Fojnica the water issues from a fault in Carboniferous schists with a radioactivity of 3.640 muc/l and spreads in an extensive sinter terrace. Springs in the terrace increase in radioactivity the farther they are from the fault (6.11, 10.69, 17.82 muc/l) due to secondary enrichment of uranium and radium in the sinter. A well drilled at the fault passed the schists and penetrated younger (probably Permo-Triassic) limestones at 24 meters. The radioactivity of the water from the limestone is now only 0.1075 muc/l. Meanwhile some thermal water still flows through the terrace. As now the radon generated through radioactive decay in the sinter is dissolved in less water, the radioactivity of the springs has considerably increased (9.269, 35.52, 37.00 muc/l). At Klokoti where CO2 escaped from pools in a bog, the gas showed a radioactivity of 3.74 muc/l). Drilling gave gas and water with a higher radioactivity (8.526 muc/l). Here a well passed through 74 meters of alluvial and diluvial clay of low radioactivity and entered Carboniferous schists where it stopped at a depth of 202 meters. The increase of the radioactivity of the gas is due to the fact that while the gas before passed slowly through the clay it now reaches the surface quickly, thus diminishing the radioactive decay of radon. (Auth)

69
Mogarovskiy, V.V., A.K. Mel'nichenko, and V.I. Kozyrev; Academy of Science of the Tadzhik SSSR, Institute of Geology, Dushanbe, USSR

Radiogeochemical Features of the Granitoids of the Gissar Batholith: Trends in the Distribution of U and Th in the Rocks of Central Tadzhikistan. Geochemistry International 8(2):259-267.(1971)

The Gissar granitoids show an increase in uranium content from 3.3 ppm to 4.9 ppm in the quartz diorites and granodiorites in intrusive phase I to the biotite granites of intrusive phase III. This rise in the uranium content is then followed by a decrease to 4.0-4.5 ppm. The mean uranium concentration for the batholith as a whole is 4.4. Statistical treatment indicates that the U-Si correlation is decisive in the quartz diorites and granodiorites of phase I. There is a close U-F correlation in the granites, and much weaker correlations for uranium with K and Si. Thorium behaves much as does uranium, increasing from 12 to 28 ppm from phase I to phase II and falling to 18-22 ppm in the later phases. The mean content of thorium for the entire batholith is 20 ppm. The mean Th/U ratio is 4.6, and thorium is closely correlated with uranium during differentiation. (JMT)

70
Moore, R.T.; Arizona Bureau of Mines, Geological Survey Branch, Tucson, AZ; USGS, Denver, CO

Chemical Analysis of Coal Samples from the Black Mesa Field, Arizona. Arizona Bureau of Mines Circular 18; 14 pp.(1977)

Representative samples of the important coal deposits being mined on Black Mesa were sent to the USGS for analysis. The specific sample locations, the results of analyses, and comparative data on the content of various elements and oxides for Black Mesa and Rocky Mountain Province coals are shown. Uranium concentrations ranged from 1.1 ppm to less than 0.2 ppm. The arithmetic mean for uranium was 0.6 ppm; the geometric mean for uranium was 0.4 ppm; and the geometric deviation was 2.7. (PAG)

71
Moreau, M.; COGEMA, Fontenay-aux-Roses, France

L'Uranium et les Granitoides: Essai d'Interpretation. Geology, Mining and Extractive Processing of Uranium, Jones, M.J. (Ed.), Proceedings of a Symposium, London, January 17-19, 1977. Institute of Mining and Metallurgy, London, (pp. 83-102), 171 pp.(1976)

In recent years petrologic and geochemical research has been carried out on plutonic rocks. Various mechanisms, which could control the distribution of uranium in granitoids, have been reviewed. In France, intragranitic mineralization in relationship to the acidic granitoids (Leucogranites), which are well developed in the western Massif Central is considered. In the eastern Massif Central the influence of leucogranites is apparently absent. The leucogranitic uranium mineralizations are located in a thickened sialic area, metamorphosed in the Borrovian grade. In the leucogranite bodies, the geochemical content is higher and uranium is mainly within the microcrystals of non-thoriferous uraninite, whereas the veins are strictly located within the leucogranite bodies. In the ante-Hercynian basement of the eastern Massif Central Area, covered unconformably with rather thin Devono-Dinantian series, no obvious affinity with a particular granitoid is seen. In that case the uraninite crystals have a notable thorium grade; the vein-type mineralizations are controlled by the basement-cover interaction. The concept of 'fertile' granites should only be applied to thickened sialic crusts, where the mineralizing fluids, originated from the anatexis, are correlated with the vein-type fluids. Such a concept must be rejected when thin or normal sialic crusts are concerned. There, the geochemical preconcentration phenomena do not seem related to vein-type mineralization. These concepts are extended to other uraniferous areas, such as the Rossing deposit in South West Africa and the Spokane district, Western USA. (Auth)(PAG)

72
Mueller, G.

The Distribution of Uranium in Naturally Fractionated Organic Phases. International Geological Congress, Proceedings of a Conference, Copenhagen, Denmark, 1960. Part 15, Genetic Problems of Uranium and Thorium Deposits, (pp. 122-132), 164 pp.(1960)

Sets of two or more distinct carbonaceous phases occurring side-by-side or at close proximity to each other were studied to determine the relative degrees of affinities towards U through "geological timescales," and the diverse types of organic molecules constituting each of them. It was found that within the hydrothermally differentiated types of bitumen sets from Derbyshire, England, the U percentage very markedly increases with the C/H of the organic mineraloid, and further that in phases with approximately equal C/H, that of higher O/C is somewhat more radioactive. Within the Sta. Juana district of Chile some granitized Triassic conglomerates were found grading into unaltered sediments within as little as fifty yards. The abundant plant remains show progressive graphitization towards the batholith, with the appearance here and there of droplets of evidently distilled bitumens, which were found poorer in uranium than the former, non-mobilized skeletal residues. The radioactivity of both phases tends to increase somewhat towards the main intrusive mass. (Auth)

73
Naumov, G.B.

Some Physico-Chemical Peculiarities of Uranium Behavior in Hydrothermal Solutions. Geokhimiya 2:115-132.(1961)

The most typical components of uranium-containing hydrothermal solutions are carbon

dioxide, silicic acid, fluorine, and sulphur; the most typical cations are alkaline metals. A study of uranium behavior showed transport in the form of complicated complex ions, among which the carbonate and the fluoride ions are the most probable. The processes of complex formation provide a reliable transport of hexavalent uranium under conditions where UO2(+2) is reduced to UO2. On the basis of an analysis of the behavior of complex uranium ions, the principle causes of uranium deposition were traced. (Auth)

74
Naumov, G.B., and I.L. Khodakovskiy; Vernadskiy Institute of Geochemistry and Analytical Chemistry, Academy of Sciences of the USSR, Moscow, USSR

Thermodynamic Analysis of Mineral Formation Factors for Hydrothermal Deposits. Geochemistry International 9(6):1051-1056.(1972)

The various models for hydrothermal uranium ore formation can be divided into two groups. The first group employs the temperature variation in the solubility of minerals for uranium parageneses and does not take into account complexing. The second group considers complex ions as the main form of uranium transport. Uranium in nature can exist in various stages of oxidation, so the model should include the corresponding redox equilibria. As an example, the authors took the equilibrium between pyrite and hematite, which corresponds to an observed uranium paragenesis. In this case, the constant for the first model, including the redox equilbria and stepwise hydrolysis in uranium, gives a maximum considerably above 350 degrees C. While the model incorporating carbonate complexing at a constant CO2 concentration has a maximum in the range of 50 to 100 degrees C. If the temperature variation in the content of dissolved CO2 is included in the model in accordance with values measured on gas-liquid inclusions with various homogenization temperatures, the maximum shifts to about 150 degrees C, which corresponds to values obtained from the formation temperatures of uraninite parageneses. (JMT)

75
Naylor, R.S., R.H. Steiger, and G.J. Wasserburg; California Institute of Technology, Pasadena, CA; Massachusetts Institute of Technology, Cambridge, MA; Eidg. Technische Hochschule, Zurich, Switzerland

U-Th-Pb-Sr Systematics in 2700 X 10(E+6)-Year Old Plutons from the Southern Wind River Range, Wyoming. Geochimica et Cosmochimica Acta 34(11):1133-1159.(1970, November)

To distinguish between episodic and continuous-diffusion loss mechanism, and to compare the response of different parent-daughter systems to metamorphism, a series of well exposed plutons, all about 2700 m.y. old were studied. The Louis Lake granodiorite pluton in the Southern Wind River Range of Wyoming was selected to represent granitic rocks only slightly affected by later disturbances (intrusion of Precambrian diabase dikes and gentle Laramide uparching). Rb-Sr Data on total rock samples form a linear array on the Sr-evolution diagram, indicating that the pluton was emplaced 2630 plus or minus 20 m.y. ago with an initial Sr 87/Sr 86 ratio of 0.702 plus or minus 0.001. Data on cogenetic zircon fractions form a linear array on a couple Pb-U evolution diagram with a primary intercept of 2687 plus or minus 15 m.y. The secondary intercept of 130 plus or minus 100 m.y. is distinctly lower than the 480 to 660 m.y. intercepts predicted by single-phase continous-diffusion models. If the zircons reflect Laramide disturbance, this is not detected by the Rb-Sr data on mineral separates. Disturbance of these data is readily apparent only in rocks with high Rb/Sr ratios and has yielded no apparent secondary ages younger than 2000 m.y. (Auth)(JMT)

76
O'Brien, T.D.; University of Minnesota, Minneapolis, MN

Uranium Occurrences in Asphaltites. RME-3040; 6 pp.(1953)

The purpose of the paper is to establish the form in which uranium occurs in asphaltite and then determine its relationship to the organic (hydrocarbons) constituents. Extractions with organic solvents yielded negligible amounts of

uranium. Basic solutions were most effective. A 10 percent sodium carbonate solution at reflux temperatures for 3 days extracted over 20 percent of the contained uranium. Evidently this uranium is present as an organo-uranium compound because upon acidification a yellow solid, containing carbon, hydrogen, nitrogen, oxygen, and uranium is obtained. Solution of simple uranium compounds, or of the oxides by carbonate complexing, do not yield precipitates upon acidification. Distilled water extractions of the ore yield iron in the ferrous condition and sulfate, but no uranium. Repeated extractions of the same sample with fresh portions of distilled water show a decrease in pH from 6.5 to 4 indicating a relatively high acid content. Heating of the ore in an inert atmosphere yields a yellow sublimate at 250-300 degrees C. This sublimate seems to be the same organo-uranium compound as obtained in the sodium carbonate extraction. Chemical analysis and the infra-red spectrum give insufficient data to establish its identity. (Auth)

77
O'Connell, M.F., and R.F. Kaufmann; US EPA, Office of Radiation Programs, Las Vegas Facility, Las Vegas, NV

Radioactivity Associated with Geothermal Waters in the Western United States. ORP/LV-75-8A; 25 pp.(1976, March)

This report presents the radioanalytical results on water samples obtained from approximately 140 hot springs and shallow wells in eight western states. Sample locations were selected upon current or potential use as a geothermal heat source. Specific nuclide analyses were completed for radium-226, uranium-234, uranium-238, thorium-230, thorium-232, and dissolved radon-222. Accompanying these results is a brief overview of trends and rough correlations of radiochemical data with other inorganic data from previous studies. (Auth)

This paper was presented at the Rocky Mountain Section meeting of the American Association of Petroleum Geologists-Society of Economic Paleontologists and Mineralogists, June 1-4, 1975 and the 1975 Health Physics Society annual meeting July 14-17, 1975.

78
Ostrovskaya, G.Ya.

Uranium in Rocks of Phosphorite-Bearing Formations. Soviet Journal of Atomic Energy 36(1):237-242.(1974, July)

A classification of phosphorites, illustrating the relationship between uranium and phosphorites is discussed in this article. The 12 types of phosphorite-bearing formations are combined into three groups. Deposits formed in the initial or later stages of development of geosynclines, and within young or ancient platforms, are distinguished. Elevated uranium concentrations are observed only in rocks of marginal siliceous formations. In addition, tectonics plays a role in the concentration of uranium in phosphorites. Often, uranium-bearing phosphorites differ from barren ones only by their tectonic position. Terrigenous-carbonate phosphorite formations occupy enormous areas and are of great economic importance, but their uranium content is negligible. Deposits of the glauconitic group of formations, formed in the platform stage, are usually concretionary. Of the formations in this group, only the glauconite-opoka formations contain significant uranium concentrations. Continental phosphate deposits typically have a uranium content of about 0.00n percent, reaching 0.n percent in some cases. Such formations are relatively rare and generally are associated with the bones of large vertebrate animals and birds. (JMT)

79
Overstreet, W.C., J.J. Warr, Jr., and A.M. White; USGS, Washington, DC

Influence of Grain Size on Percentage of ThO2 and U3O8 in Detrital Monazite from North Carolina and South Carolina, USA. Second Seminar on Geochemical Prospecting Methods and Techniques, Peradeniya, Ceylon, September 10-20, 1970. United Nations, (pp. 143-153), 413 pp.(1970)

Chemical analyses for ThO2 and U3O8 content in 81 sized fractions of detrital monazite from 33 drainage basins in North Carolina and South Carolina disclosed a strong tendency for the percentage of ThO2 to vary according to particle sizes of monazite at each locality. Higher

percentages of ThO2 are associated with coarse-grained monazite rather than with fine-grained monazite. This relation for thorium is thought to result from the tendency of certain grain-size ranges of the detrital monazite to be associated with the origin of the monazite in specific rock units. The role of size in relation to tenor of U3O8 was not fully brought out by the study, owing possibly to the use of two small a separation in grain size. Differences in percentage of U3O8 were greater than those that could be attributed to analytical procedure, and more analyses are required to define the trends of these differences. Knowledge that the composition of a detrital mineral may vary with grain size and that grain-size distribution tends to vary by rock type might actually be used to advantage in geochemical exploration. (Auth)

80
Page, L.R.; USGS, Washington, DC

Some New Mineralogical, Geochemical and Geologic Aids in Uranium Exploration. Peaceful Uses of Atomic Energy, Proceedings of the 2nd International Conference, Geneva, September 1-13, 1958. United Nations, Vol. 2, Survey of Raw Material Sources, (pp. 123-125), 843 pp.(1958)

Study of the distribution of elements and the alteration of detrital minerals in sandstones of the Slick Rock district has resulted in the recognition of the asymmetric distribution of various minerals on either side of the roll ore bodies and the relation of this distribution to the path of mineralizing solutions. One of the most useful geochemical techniques applied to understanding altered ores is the study of radioactive disequilibrium. Use of the radioluxograph has aided greatly in speeding up studies of distribution of the radioactive minerals. The use of lead isotope analysis of minerals such as jarosite, limonite, and other secondary minerals is suggested as a method of indicating leaching of uranium with downward migration to unoxidized zones. Fundamental data has been contributed on the problem of leaching uranium from volcanic tuffs by ground water and precipitation in sandstones. Isotope variations in the lead of nonradioactive minerals, such as galena or pyrite, have potential significance in prospecting for regional enrichments or local concentrations of uranium and thorium. Research on uraniferous limestones in New Mexico have isolated and identified, with synthesized materials, a uranium-bearing ester of phthalic acid, a petroleum derivative, as the organic compound which when irradiated, yields asphaltite or the thucholite-type hydrocarbons in some deposits. Stream sampling as a reconnaissance tool can narrow the area in which detailed stream and soil sampling are warranted. These are the more important advances in mineralogy, geochemistry, and geologic knowledge which have aided in the recognition and understanding of uranium deposits. (PAG)

The paper is a summary based on nine other papers presented at the conference.

81
Pal, S., D.J. Terrell, and E. Herroro Bervera; Universidad Nacional Autonoma de Mexico, Instituto de Geofisica, Mexico City, Mexico

Radiometric Determination of Uranium, Thorium and Potassium in Some Rocks of the Guanajuato Mineral District, Mexico. Geofisica Internacional 14(4):329-335.(1974)

Uranium, thorium and potassium contents of some igneous and sedimentary rocks of the Guanajuato Mineral District have been measured by gamma-ray scintillation spectrometry. Preliminary measurements show that the area studied is not a province of high radioactive contents. The data obtained for different rock types is consistent with what has been found in other areas. The average K/U ratio is close to 1 x 10(E+4) and K/Th ratio 3.9 x 10(E+3) in agreement with the figures established in the literature. (Auth)

82
Pluman, I.I.; Novosibirsk Geological Bureau, Novosibirsk, USSR

Distribution of Uranium, Thorium and Potassium in the Sedimentary Rocks of the West Siberian Platform. Geochemistry International 12(3):97-107.(1975)

The distribution of the principal natural radioactive elements in the sedimentary rocks of the West Siberian platform was investigated on the basis of the data from gamma-ray logging of boreholes, luminescence analysis, and gamma-ray spectrometric and chemical analyses of cores. The average uranium and thorium content of the sands and sandstones of the platform was 1.8 and

5.8 ppm, respectively. Siltstones averaged 2.1 ppm uranium and 7.1 ppm thorium and the argillites and clays of the platform contained an average of 2.6 ppm uranium and 7.3 ppm thorium. The highest uranium and thorium contents of the sedimentary rocks of the Siberian platform came from the bituminous argillites. These rocks contained an average of 23 ppm uranium and 7.8 ppm thorium. (JMT)

83
Plyushchev, Ye.V., and L.A. Ryabova; All-Union Geological Research Institute, Leningrad, USSR

Accumulation Levels of U and Th in Hydrothermal Minerals. Geochemistry International 11(4):820-830.(1974)

Determinations of trace amounts of uranium and thorium in 240 nonradioactive hydrothermal minerals from a series of deposits and mineralized zones were reported. From these determinations, the trend in the behavior of the radioelements in various hydrothermal processes was approximated. In the Greisen formation the characteristic sequential crystallization is as follows: quartz - muscovite - fluorite - pyrite - ore minerals. In this direction there is a gradual accumulation of uranium, with a maximum in the ore minerals. Thorium shows a slight reverse trend, but there is selective accumulation of it in fluorite. During the formation of secondary quartzites, the sequence is quartz - sericite - pyrite - ore minerals. In this sequence, uranium and thorium behave similarly, with no tendency to separate even at the stage where the ore minerals are deposited. The highest concentrations of the radioelements occur in the mica and pyrite. The gold-bearing beresites are characterized by the following sequence: quartz - sericite - carbonate - pyrite. In this process, the uranium and thorium behave identically. During the formation of the molybdenum-bearing beresites, the following series is found: quartz - hydromuscovite - cholorite - carbonate - pyrite - ore minerals. There is maximum differentiation of the uranium and thorium in this process, along with marked accumulation of uranium and reduction in thorium content for the final products. There is additional accumulation of radioelements, especially thorium, in the earlier micaceous minerals; a feature specific for hydrothermal formations. (JMT)

84
Putintsev, V.K., G.V. Ditmar, V.A. Maksimovskiy, and V.A. Selivanov; All-Union Geological Institute, Leningrad, USSR

Uranium and Thorium in the Igneous Rocks of the Bureinsk Massif. Geochemistry International 9(4):583-588.(1972)

More than 2000 determinations of uranium and more than 600 determinations of thorium were made in samples collected from the Bureinsk Massif. The uranium was determined by luminescence analysis and the thorium was determined radiochemically and by the ion exchange photometric method. There is no increase in uranium and thorium contents with time in the massif. The concentration of uranium and thorium show a definite correlation with the contents of SiO2, K2O, Na2O, and CaO. Uranium content increases with thorium content, and the average Th/U ratio is near 4.5. (JMT)

85
Rafal'skiy, R.P.

New Data on Equilibrium Redox Reactions that Occur Under Hydrothermal Conditions in the Presence of Uranium. Doklady Akademii Nauk SSR 199(2):448-451.(1971)

From a number of calculations involving oxidation-reduction reactions and the equilibrium constants of these reactions, the author concluded that the activity of the uranyl ion in solution is significant only in a strongly oxidizing environment. This type of environment is not likely to be present under endogenous conditions, although the possibility of the transport of uranium as uranyl monosulfate by hydrothermal solutions cannot be excluded. The activity of uranyl monosulfate may reach 10(E-2) to 10(E-6) at relatively low values of fO2. This range corresponds to the stability fields of sphalerite and pyrite and it is only slightly greater than the fO2 value found at the boundary between the stability fields of galena and anglesite. (JMT)

86
Reimer, G.M.; USGS, Washington, DC

Uranium Analysis of Single Drops of Natural Waters Using the Fission-Track Technique. USGS Open-File Report 76-239; 19 pp.(1976)

The fission-track technique provides a sensitive analytical method for uranium analysis of natural waters using a single drop of water. It provides information as to the location of uranium-in solution or in the suspended particulates. Samples may be collected in the field by evaporating a drop of water on a detector, and samples may then be analyzed by returning the detector to the laboratory. Advantages of this technique are pico-gram sensitivity [10 (E-12)g] for uranium on single drops of water, maintenance of sample integrity during transport and storage, and the ability to discern whether the uranium is in solution or in the suspended material. The analytical error is generally plus or minus 10 percent over the entire range of concentrations. (Auth)(PAG)

87
Rich, R.A., H.D. Holland, and U. Petersen; Harvard University, Cambridge, MA

The Chemistry of Uranium Transport in Hydrothermal Solutions. Hydrothermal Uranium Deposits, R.A. Rich, et. al., Elsevier Scientific Publishing Company, New York, (pp. 35-51), 264 pp.(1977)

Natural uraninite spans nearly the entire compositional range between UO2 and U3O8, but the phase relations of the U-O system below 400 degrees C are not well known. At 25 degrees C the stability field of uraninite is bordered on the high fO2 side by the UO3 field, or, in the presence of water, by the stability field of either UO3 x 2H2O (schoepite) or UO3 x H2O. At CO2 pressures in excess of 10(E-2.2) atm., rutherfordine (UO2 x CO3) is stable at room temperature. Toward higher temperatures, progressively larger CO2 pressures are required to stabilize this mineral. Solubility measurements of hydrated UO3 at 25 degrees C have shown that in acid solutions hexavalent uranium is present largely as UO2(OH)+ and UO2+2. In the system U-O-H2O-HCl the concentrations of uranium in solution saturated with respect to UO3 x H2O or UO3 x 2H2O is about 10 ppm in neutral solutions, rising rapidly with decreasing pH, but increasing very slowly with rising pH. The solubility of UO2 at low values of fO2, where only U+4 ions are stable is probably much less than 0.2 ppm at near-neutral values of pH. In the presence of 1 atm. of CO2 rutherfordine is stable at 50 degrees C. The concentration of uranium in solutions saturated with respect to rutherfordine between 25 and 50 degrees C passes through a minimum between pH 4.4 and 5.6. Sulfate and fluoride complexes of uranium may be of importance in uranium transport, but their effect is probably less pronounced than that of O-2, OH-, and CO3-2 complexes. With increasing temperature, the solubility of UO2 in equilibrium with UO3 probably passes through a maximum near 260 degrees C. There is a rapid decrease in the solubility of UO2 below 200 degrees C and probably also above 300 degrees C. The presence of NaHCO3 increases the concentration of uranium in solutions equilibrated with UO2 and UO3 throughout the hydrothermal range, although the uranium concentration in solutions of a given NaHCO3 concentration seems to decrease rapidly with increasing temperature above 25 degrees C. (JMT)

Phase diagrams for the U-O and U-O-C-H systems are presented, as well as diagrams illustrating the effect of pH, fO2, and temperature on the uranium oxygen system.

88
Rich, R.A., H.D. Holland, and U. Petersen; Harvard University, Cambridge, MA

The Distribution of Uranium. Hydrothermal Uranium Deposits, R.A. Rich, et. al., Elsevier Scientific Publishing Company, New York, (pp. 2-9), 264 pp.(1977)

Uranium is a lithophile element which is enriched in the upper crust. The average crustal abundance of uranium is about 2 ppm. Uraninite is the most abundant uranium mineral and the only commonly occurring tetravalent uranium mineral. Coffinite is found in minor amounts in some hydrothermal uranium deposits, but the most important uranium ore mineral in hydrothermal deposits is pitchblende; the fine-grained, massive, botryoidal, or sooty variety of uraninite. In igneous rocks, high uranium concentrations usually correlates with high concentrations of potassium and silica. Mafic and ultramafic rocks normally contain less than 1 ppm uranium, while granitic and alkalic rocks usually contain 2 to 4 ppm uranium, and felsic rocks (especially their pegmatitic derivatives) often contain more than 10 ppm uranium. Felsic minerals in igneous rocks usually contain much less uranium than biotite, hornblende, and pyroxene, and the highest uranium concentrations are found in accessory minerals such as xenotime, zircon, monazite, sphene, allanite, epidote, and apatite. The average abundance of uranium in sedimentary rocks is

about the same as the average in igneous rocks. Clean sandstone and pure limestones usually contain very little uranium, but uranium enrichment in certain shales and phosphorites is pronounced. The uranium content in sedimentary rocks, especially shales and sandstones often correlates with clay and organic carbon contents. The uranium content of metamorphic rocks is quite variable, and tends to reflect the uranium concentrations of their protoliths. Some very highly metamorphosed rocks, however, appear to be depleted in uranium relative to their lower grade and unmetamorphosed equivalents. It has been suggested that uranium moves upward in the crust during granulite grade metamorphism. Most natural waters contain no more than a few ppb dissolved uranium. The concentration of uranium has a relatively constant value of 1-4 ppb. The uranium content of most surface and near surface continental waters is somewhat lower. In natural waters, uranium concentrations greater than 100 ppb are quite rare, and generally have been found only in aquifers containing uranium mineralization. (JMT)

89
Rose, A.W.; Pennsylvania State University, Department of Geosciences and Mineral Conservation Section, University Park, PA

The Effect of Cuprous Chloride Complexes in the Origin of Red-Bed Copper and Related Deposits. Economic Geology 71:1036-1048.(1976)

Geological, mineralogical, and isotope data indicate that redbed copper deposits are introduced into their host rocks after sedimentation by flowing subsurface waters approximately in equilibrium with hematite, quartz, feldspar, and mica at temperatures less than about 75 degrees C. Precipitation of copper is caused by encountering a reducing environment. In most normal oxidizing terrestrial ground waters, solubility of copper is less than 1 ppm at reasonable pH values, so these waters are relatively ineffective in transport of Cu. However, cuprous ion (Cu+) forms the complex ions CuCl2(E-1) and CuCl3(E-2) with formation constants of 10(E+5.4) and 10(E+5.8) at 25 degrees. These complexes allow solubilities of about 100 ppm Cu in 0.5 m Cl- at intermediate Eh in the stability field of hematite at pH 7.0, and solubilities of 6 ppm at pH 8.2. Weaker complexes of Cu(E+2) with OH(E-1), SO4(E-2), SO3(E-2), and Cl(E-1) are known but have comparatively little effect on copper solubility in most natural waters. Most red bed copper and cupriferous sandstone-type uranium deposits are associated with evaporites which could have furnished chloride-rich ground waters. Escape of connate marine waters from underlying marine sediments may have furnished a copper-transporting fluid in other cases. (Auth)(MLB)

90
Rosholt, J.N.; USGS, Washington, DC

Radioactive Disequilibrium Studies as an Aid in Understanding the Natural Migration of Uranium and its Decay Products. Peaceful Uses of Atomic Energy, Proceedings of the 2nd International Conference, Geneva, September 1-13, 1958. United Nations, Vol. 2, Survey of Raw Material Sources, (pp. 230-236), 843 pp.(1958)

Four generalized types of radioactive disequilibrium involving the uranium series in sedimentary rocks are discussed in this paper: 1) the deficiency of all daughter products where the relationship is that U exceeds ePa 231, which exceeds eTh 230, which exceeds eRa 226; 2) the deficiency of Th 230 where generally eAc 227 equals or exceeds U, which equals or exceeds eRa 226, which equals or exceeds eTh 230; 3) the radioactive sources where the radioactivity is composed almost entirely of Ra 226 and its immediate daughter products or combinations of Ra 226 and Ra 228 or Ra 226 and Ac 227; and 4) the deficiency of uranium in radioactive sources which contain much larger equivalent amounts of the uranium series daughter products. Possible explanations and speculations of the causes of these types of disequilibrium are presented with an approach of multiple hypotheses. (RAF)

91
Rosholt, J.N.; University of Miami, Miami, FL

Uranium in Sediments. Ph.D. Thesis.(1963)

An oceanographic approach is used to study the distribution of abnormal occurrences of uranium in sediments. These occurrences predominate in marine phosphorites, black marine shales, and deposits in terrestrial-fluvial sandstones and ancient conglomerate. In early Paleozoic times, marine shales accounted for the majority of uranium deposition. By the beginning of Tertiary time, the balance had shifted to predominant deposition in marine phosphorites, which continued to the present. Much smaller total

quantities of uranium are associated with terrestrial sandstones and ancient conglomerates, although its concentration is greater and its economic recovery is more feasible. All the abnormal occurrences fit into a unique niche in the hydrologic cycle, and emplacement was largely controlled by cycles of organic substances in water. Radiochemical analyses of Pa 231, Th 230, and Ra 226 were made on a few hundred samples from sandstone-type uranium deposits. These results, in comparison to the uranium content of samples, indicate that much of the uranium in terrestrial sediments is presently in a slow, continual state of migration toward to ocean. (NSA)

92
Rosholt, J.N., B.R. Doe, and M. Tatsumoto; USGS, Denver, CO

Evolution of the Isotopic Composition of Uranium and Thorium in Soil Profiles. Geological Society of America Bulletin 77:987-100.(1966)

Mass-spectrometric and alpha-spectrometric analyses for the isotopic composition of U 238, U 235, U 234, Th 232, and Th 230 have been made on several soils and soil profiles in glacial-derived parent material, volcanic rock, and shale. Three deep profiles from Minnesota represent typical well-developed soils on till and loess of Wisconsin age continuously sampled to depths of 6, 7, and 10 feet, respectively. Results on individual soil horizons, in these three profiles, show similar trends in the variation of U 234/U 238 and Th 230/U 238 ratios, the predominant features being excess Th 230 and deficient U 234 compared to U 238. The other soils and soil profiles have different variations which can be correlated by use of a model to describe uranium migration. The data collected provided information for interpreting the causes of uranium migration in soils and for constructing a tentative model to explain the isotopic evolution of uranium and thorium in soil profiles. The proposed model indicates that (1) uranium was leached at depth in the profile, (2) preferential leaching of U 234 was continuous in the soil, and (3) upward capillary migration of a fraction of the uranium with above-normal U 234/U 238 ratio tended to make uranium of high U 234 ratio available for isotopic exchange in upper soil horizons and for assimilation in organic complexes in surface soils which are rich in organic matter. Thus some of the organic-rich surface soils, which have had considerable time to develop, contain uranium with excess U 234 compared to U 238. Interpretation from this model suggest that remixing of radioisotopes by geochemical processes contributes significantly, along with the usual physical processes of radioactive growth and decay, toward producing an isotopic composition near radioactive equilibrium. (Auth)

93
Rosholt, J.N., W.R. Shields, and E.L. Garner; USGS, Denver, CO; National Bureau of Standards, Washington, DC

Isotopic Fractionation of Uranium in Sandstone. Science 39:224-226.(1963)

Relatively unoxidized black uranium ores from sandstone deposits in the western United States show deviations in the uranium 235 to uranium 234 ratio throughout a range from 40 percent excess uranium 234 to 40 percent deficient uranium 234 with respect to a reference uranium 235 to uranium 234 ratio. The deficient uranium 234 is leached preferentially to uranium 238 and the excess uranium 234 is believed to result from deposition of uranium 234 enriched in solutions from leached deposits. (Auth)

94
Roubault, M., and R. Coppens; Universite de Nancy, Centre de Recherches Radiogeologiques, France

Etude Radiogeologique D'Une Partie Du Massif Granitique De Mortagne (Vendee) - France. International Geological Congress, Proceedings of a Conference, Copenhagen, Denmark, 1960. Part 15, Genetic Problems of Uranium and Thorium Deposits, (pp. 78-97), 164 pp.(1960)

Systematic studies in the distribution of uranium in granite have been made on samples obtained from shallow drill holes on a 500 m grid in the Mortagne s/Sevre batholith (Vendee). The chemical analyses give the content of the classical elements (SiO_2, Al_2O_3, Fe_2O_3, FeO, MgO, CaO, MnO, Na_2O, K_2O, TiO_2, P_2O_5, H_2O) and the tungsten was determined by spectrography. The uranium content has been determined fluorimetrically and the distinctions between the fixed and the mobile uranium have also been determined. The global radioactivity has been measured in the field by a Geiger-Mueller counter

and in the laboratory by counting the alpha rays on nuclear plates. The content of radon of waters of the region under study had been determined by scintillation. The sections permitted a petrographical study and the determination of the distribution of uranium by autoradiographical process. Many results gave isolines and rectangular and triangular graphics. After studying the statistical data, it was possible to establish relationships between the principal elements, the uranium, and major constituents. It was also possible to follow the variation in the uranium distribution as a function of alteration and to suggest hypotheses regarding the formation of recent autunite and the genesis of some uraniferous deposits. (Auth)

95
Russell, W.L.; Stanolind Oil and Gas Company, Tulsa, OK

Relation of Radioactivity, Organic Content, and Sedimentation. Bulletin of the American Association of Petroleum Geologists 29(10):1470-1494.(1945, October)

A comparison between the radioactivity and organic content of 510 samples of sedimentary rocks indicates a marked relation between certain types of organic content and radioactivity. Marine oil shales are associated with exceptionally high radioactivity, coals with abnormally low radioactivity, and other types of organic matter with intermediate radioactivities. An analysis of the material balance between sedimentary and igneous rocks indicates that the sediments should have about the same radioactivity as the igneous rocks from which they were derived; the averages of the tests seem to confirm this conclusion if the igneous source of the sediments resembles a granite. An analysis of the data bearing on the radioactivity of deep-sea deposits and oil shales indicates an evidence of a general increase in radioactivity with slowness of deposition. (Auth)

96
Santos, E.S.; USGS, Denver, CO

A Characteristic Pattern of Disequilibrium in Some Uranium Ore Deposits. Journal of Research of the USGS 3(3):363-368.(1975)

Redistribution of radium-226 in uranium ore deposits produces a characteristic pattern of disequilibrium in which uranium is greater than equivalent uranium in high-grade samples and equivalent uranium is greater than uranium in low-grade samples. The redistribution is a continuous process in uranium deposits, and the resulting pattern of disequilibrium is itself a system in equilibrium. (Auth)

97
Saprykina, T.V.; Academy of Sciences USSR, V.I. Vernadskii Institute of Geochemistry and Analytical Chemistry, Moscow, USSR

Distribution of Uranium in the Rocks of the Lovozero Alkali Massif. Geochemistry 5:565-570.(1959)

The Lovozero Massif is thought to have formed in four intrusive phases. The rocks of the first and oldest phase are poikilitic nepheline syenites, porphyritic nepheline syenites, nepheline syenites, equigranular nepheline syenites and subordinate foyaites and urtites. All of these rocks occur as xenoliths in the rocks of the second and third intrusive phases. The complex of lujavrites, foyaites, and urtites of the second intrusive phase forms the largest part of the massif. The rocks of the third phase overlie those of the second phase. These rocks are composed of lujavrites, juvites, and eudialytites. The fourth phase is composed of monchiquite, fourchite, alkali basalt, and tinguaite dikes, which cut all the rest of the rocks. It was found that there is a regular increase in the uranium content from the rocks of the first intrusive phase to those of the third and later phase. The content of uranium in the monchiquite dikes of the lamprophyre group (fourth intrusive phase) is much lower than in the nepheline syenites of the first three phases. The rocks of each intrusive phase have a higher uranium content if they contain lovozerite, loparite, or eudialyte. The average uranium content in the nepheline syenites of the Lovozero massif is 16 ppm; four times as high as the average uranium content in granites. (JMT)

98
Saraswat, A.C., H.N. Varada Raju, P.C. Taneja, V.B. Bargaja, and A.V. Sankaran; India Department of Atomic Energy, Atomic Minerals Division, New Delhi, India

Geochemical Data on the Uraniferous Phosphorites of Mussoorie, Dehra Dun District, Uttar Pradesh, India. Second Seminar on Geochemical Prospecting Methods

and Techniques Peradeniya, Ceylon, September 10-20, 1970. United Nations, (pp. 79-187), 413 pp.(1970)

Samples of phosphorite from the Mussoorie area in the Dehra Dun district were analyzed for uranium. The samples were uraniferous and contained as much as 0.1 percent eU3O8, considerably higher than amounts in other phosphorites. The uranium seems to be adsorbed in both the organic and phosphate phases of the rock. Phosphorite and associated rocks of the Mussoorie area were deposited in a shallow to deep marine environment that fluctuated both in time and space. The high contents of Mo, Ni and Ba in these rocks tends to confirm this environment. The P2O5 content of the phosphorites is low, but the high values of uranium, molybdenum, nickel, and vanadium indicate potential by-product recovery. (PAG)

99
Schmidt-Collerus, J.J.; Denver Research Institute, Denver, CO

Research in Uranium Geochemistry-Investigation of the Relationship between Organic Matter and Uranium Deposits, Part 2: Experimental Investigations. GJO-933-2; 192 pp.(1969, July)

The feasibility of the micropyrolysis-gas chromatography-mass spectrometry (MPGM) method for the characterization of the organic matter associated with uranium in fluviatile ore deposits was investigated. The role of biogenically generated hydrogen sulfide in the reduction and precipitation of uranium in particular in the roll-type deposits was also investigated. It was found that the MPGM method, applied successfully to the characterization ("fingerprinting") of various intractable natural biolithe, can equally well be applied to the characterization of the organic matter in uranium ore deposits and to the study of the nature of this association. The enrichment of uranium in the roll-type deposits appears to be associated principally with the organic matter present and caused by specific ligating moieties in it, the role of hydrogen sulfide is probably of a secondary nature. Nonetheless, if hydrogen sulfide was synergistically involved in the reduction and precipitation of uranium together with the organic matter it is more likely that its origin was mainly biogenic in nature because of the facile availability of organic matter as energy source for the H2S producing microorganisms. This mechanism for the H2S production appears also the less complicated one than that assumed for the inorganic mechanisms, involving oxidation of sulfides to sulfites and disproportionation of the latter to form H2S and sulfates - although the possible simultaneous partial formation by the latter reaction mechanism cannot be excluded. (NSA)

100
Schwarzer, R.R.; Rensselaer Polytechnic Institute, Geology Department, Troy, NY

The Concentration and Distribution of Uranium in Coexisting Pegmatite Feldspars by the Fission Track Method. Ph.D. Thesis; 140 pp.(1969)

The study is divided into two parts: (1) The development of a variation of the fission track method of uranium analysis which enables one to estimate the amount of uranium homogeneously distributed throughout a mineral phase. (2) The application of this modified fission track method of uranium analysis to a geologic problem and an evaluatin of its usefulness and reproducibility. A study of the concentration and distribution of uranium between coexisting feldspars from some New York State zoned pegmatites lent itself readily to investigation via the fission track method. Thirty-seven coexisting feldspar pairs from seven pegmatites were analyzed for homogeneously distributed uranium. The Poisson distribution is used as a model for estimating the amount of homogeneously distributed uranium in the feldspars. The concentration of uranium is calculated from the fission track density using the comparative standard method with a soda-lime silicate glass as a standard. The concentration range of homogeneously distributed uranium is 2 to 86 ppb in plagioclase and 1.5 to 58 ppb in K-feldspar. The pegmatites studied have been placed in a proposed differentiation sequence. The uranium content of both feldspars increases throughout the proposed differentiation sequence. The same effect has been shown for total uranium in other differentiated rock sequences. All the elements analyzed in these feldspars can be classified into three groups on the basis of behavior pattern in the pegmatite sequence: (1) a general increasing concentration, (2) a general decreasing concentration, and (3) an essentially constant concentration. Uranium is classed in the first group. The fission track method confirms that it is well suited for analyses of low uranium

concentrations, and it presents the investigator with the spatial distribution of uranium. (Auth)(MLB)

101
Scott, R.C., and P.T. Voegeli, Sr.; USGS, Denver, CO

Radiochemical Analyses of Ground and Surface Water in Colorado, 1954-1961. Colorado Water Conservation Board Basic-Data Report 7; 27 pp.(1961)

Data are presented on concentrations of silica, aluminum, iron, manganese, calcium, magnesium, sodium, potassium, bicarbonate, carbonate, sulfate, chloride, fluoride, nitrate, and orthophosphate in parts per million. Beta-gamma activity and radium concentration are shown in picocuries per liter and uranium concentration is presented in micrograms per liter. Dissolved solids (residue at 180 degrees C), hardness as CaCO3, specific conductance (umhos at 25 degrees C) and pH values are also indicated. Concentrations of other elements tested for in select samples are presented in parts per million in the remarks section of the tables. (PAG)

This report contains only data presented in tabular form.

102
Sharp, R.R., Jr.; Los Alamos Scientific Laboratory, Los Alamos, NM

Results of Elemental Analyses of Water and Waterborne Sediment Samples from the Proposed Cape Krusenstern National Monument, Alaska. LA-6945-MS; GJBX-63(77); 28 pp.(1977, August)

Water and sediment samples were collected from streams and lakes over an area of approximately 100,000 square kilometers around Kotzebue, Alaska. This sampling was by helicopter at a nominal density of one location per 23 square kilometers, and included the 1400- to 1900-square kilometer area proposed for the Cape Krusenstern National Monument. In addition to the routine field data and uranium determinations for waters and/or sediments from 89 locations sampled over the proposed Cape Krusenstern Monument, the results of analyses of 44 additional elements in 77 of the sediments from there are provided. Sample locations are shown on a 1:250,000-scale plate. The data and descriptions of the methods used are in appendices. The uranium in water was determined by fluorometry; that in sediment, by delayed-neutron counting. The sediments were also analyzed for bismuth, cadmium, copper, lead, nickel, niobium, silver, tin, and tungsten, using X-ray fluorescence. They were further analyzed by neutron activation analysis for aluminum, antimony, arsenic, barium, bromine, calcium, cesium, cerium, chlorine, chromium, cobalt, dysprosium, europium, gallium, gold, hafnium, iron, lanthanum, lutetium, magnesium, manganese, mercury, potassium, rubidium, samarium, scandium, sodium, strontium, tantalum, terbium, thorium, titanium, vanadium, ytterbium, and zinc. For all analyses, relative errors are generally approximately 40 percent near the lower detection limits and less than 10 percent at one order of magnitude above. (Auth)

103
Sharp, R.R., Jr., and P.L. Aamodt; Los Alamos Scientific Laboratory, University of California, Los Alamos, NM

Uranium Concentrations in Natural Waters, South Park, Colorado. LA-6400-MS; 49 pp.(1976, August)

In South Park Colorado, 464 water samples from 159 locations were obtained to test the field sampling and analytical methodologies proposed for the NURE Hydrogeochemical and Stream Sediment Reconnaissance for uranium in the Rocky Mountain states and Alaska. In the South Park area, the analytical results did not vary significantly between samples which were untreated, filtered and acidified, filtered only, or acidified only. The analytical methods of fluorometry and delayed-neutron counting (developed at LASL for the reconnaissance work), provided fast, adequately precise, and complementary procedures for analyzing a broad range of uranium in natural waters. Data generated using this methodology appear to identify uraniferous areas and should prove a valuable tool in reconnaissance surveying. (Auth)

104
Shcherbina, V.V.; All-Union Institute of Mineral Raw Materials, Moscow, USSR

Behavior of Uranium and Thorium in the Sulfate-Carbonate and Phosphate Environments of the Supergene Zone. Geochemistry 6:579-597.(1957)

In searching for radioactive ores, the method of dissemination haloes in unconsolidated deposits and the evaluation of endogenetic ore formation according to the oxidation zones of the deposit are now more and more widely used. For solving these problems it is necessary to know the geochemical behavior of uranium and thorium in the supergene zone. The following types of haloes are known: (1) haloes of a small radium with a sharp drop in the concentration gradient (high precipitability of uranium and thorium compounds); (2) a considerable dissemination halo at a distinct concentration gradient (intensive weathering of the deposit, good precipitability of compounds of the radioactive elements, a favorable relief); (3) a large dissemination halo with a small concentration change is usually produced by weak precipitability of uranium under the given conditions and a low relief; (4) haloes are essentially absent-uranium and thorium are carried in the form of easily soluble compounds not precipitated by the surrounding rocks. Depending on the conditions and the composition of the primary minerals of the ore deposit and the composition of the rocks, uranium may be transferred into the oxidation zone 1) in the form of relatively easily hydrolyzable sulfate-UO2SO4 (at pH less than 4.2); 2) in the form of colloid solutions (sols)-(UO2(OH)2)n (at pH=4.5-7.5); 3) in the form of complex uranocarbonate ions of the composition (UO2(CO3)3)(E+4) stable at pH 7.5-10.9; 4) in the form of easily soluble (usually complex) compounds with organic soil oxides. Uranium precipitates from these solutions in consequence of the following reactions: 1) hydrolysis; 2) reduction of easily soluble hexavalent compounds to almost insoluble compounds (pitchblende); 3) formation of nearly insoluble salts (phosphates, arsenates, vanadates, molydbates, silicates); 4) destruction of easily soluble complex ions; 5) selective sorption by colloid minerals and organic compounds. Thorium may be transferred in the form of the sulfate, dioxide sols and in the form of carbonate complexes. The capacity of migration of thorium is considerably less than that of uranium. Radium is transferred in the form of elementary cations Ra(+2) and coprecipitates with nearly insoluble sulfates (BaSO4) or is selectively sorbed by a number of colloid minerals. These data are of use in searching for uranium deposits by means of dissemination haloes and oxidized outcrops. (Auth)

105
Shchetochkin, V.N., V.A. Uspenskii, and L.S. Solntseva

Carbonaceous Matter in Epigenetic Uranium Deposits Associated with Zones of Stratal Oxidation. Lithology and Mineral Resources 10(2):213-225.(1975, December)

Carbonaceous matter in the uranium deposits associated with zones of stratal oxidation can be separated into two basic groups according to the patterns of spatial distribution. These groups are syngenetic ore-bearing sediments (i.e., those deposits in some sort of primary form, together with terrigenous material, in the sedimentation process) and epigenetic matter introduced into the sediments later, in connection with the development of ascending carbonic acid-bituminous process. In the carbonaceous substances studied, a strong similarity was revealed in composition and properties among varieties known to have no genetic relationship. However, carbonaceous formations linked in definite common origin and belonging to one group are typified by several different modifications of internal structure and composition. In this regard, the various geologic methods used in the study of carbonaceous matter, permit the explanation of the deposition conditions of these substances, their paragenesis, and other very important indices in connection with genesis. The presence of syngenetic carbonaceous substances contributes to the formation of rich uranium concentrations in the cementation zones of stratal oxidizing epigenesis and in primary ore zones found in stratally oxidized rocks. In both cases, this apparently is by the chemical (lowering of Eh of the medium, etc.) and sorption interaction of the carbonaceous components of the rock with uraniferous solutions. The best immediate concentrators of uranium are the carbonized plant fragments and above all their vitrainized varieties. The role of epigenetic carbonaceous compounds in the formation of transported and primary uranium ores is varied. The significance of bitumens, like syngenetic carbonaceous matter apparently leads mainly to a decrease in the oxidation-reduction potential of the infiltrating uraniferous waters, which contributes to more contrasting ore deposition in the cementation zones. It is possible that joint migration of uranium and several varieties of

carbonaceous substances took place in solutions that were reducing with respect to iron. This agrees with a whole series of geological facts which are evidence of the active participation of the ascending carbonic acid-bituminous process in the formation of primary uranium concentrations found in stratally oxidized rocks. (JMT)

106
Shmariovich, E.M.

Uranium Content of Unaltered Sedimentary Rocks of Various Types and Oxidation Zones. Lithology and Mineral Resources 8(2):211-221.(1974, January)

The characteristics of the uranium contents of Mesozoic-Cenozoic deposits of various different genetic and geochemical types are discussed. It is established that on the whole these contents correspond to the Clarkes of concentration (1-4 ppm). Somewhat higher uranium contents are exhibited by rocks rich in sorbents and precipitants, particularly those in additional concentrations of uranium are added in the diagenesis stage of continental sediments. From a comparison of the data on the uranium contents of unaltered rocks and those subjected to surface and subsurface oxidation, it is inferred that the primary dispersed contents in the adjoining sedimentary strata were not an important source of uranium in the formation of the blanket epigenetic deposits investigated. (JMT)

107
Sidorenko, G.A., V.T. Dubinchuk, and E.V. Kopchenova

The Mechanism of Replacement of Uraninite by Secondary Minerals. Soviet Journal of Atomic Energy 38(2):137-139.(1975, February)

Alteration of uraninite is mainly due to the oxidation of U+4 to U+6. Since the ionic radius of U+4 is 0.97 angstrom and that of U+6 is 0.80 angstrom, there is a decrease in the unit cell dimensions of the mineral resulting in structural changes. According to the particular physicochemical conditions, it was observed that uraninite develops either only uranium hydroxides, or silicates and hydroxides simultaneously. (JMT)

108
Simpson, P.R., J. Plant, and M.J. Cope; Institute of Geological Sciences, Geochemical Division, London, England

Uranium Abundance and Distribution in Some Granites from Northern Scotland and Southwest England as Indicators of Uranium Provinces. Geology, Mining and Extractive Processing of Uranium, Jones, M.J. (Ed.), Proceedings of a Symposium, London, January 17-19, 1977. Institute of Mining and Metallurgy, London, (pp. 126-139), 171 pp.(1976)

The concentration and distribution of uranium in granitic rocks from the orthotectonic Caledonides (Shetland, Aberdeen and Helmsdale) and the Herynian province (southwest England) are compared by use of the delayed neutron method of analysis and the Lexan plastic fission track method. This combination of techniques indicates whether anomalously high levels of uranium result from primary magmatic processes or from later enrichment. The geometric mean concentration of uranium in the Caledonian granites studied is 3.9 ppm uranium, with a range of 0.5 to 15.2 ppm; in the Hercynian granites the geometric mean concentration is 10.8 ppm with a range of 3.2-35.5 ppm. Statistical analysis using a two-tailed Kolmogorov-Smirnov test indicates that the observed differences in the uranium concentration of the two granite suites is significant at the 99 percent confidence level. Lexan plastic fission track studies show that the Caledonian granites contain only small amounts of primary uraniferous phases and that uranium occurs mainly in secondary minerals, such as hematite and chlorite, in zones of alteration associated with major faults. The uranium in Hercynian granites is shown to occur mainly in minerals such as zircon, apatite and sphene. The results obtained indicate that the uranium vein-type mineralization of southwest England is comagmatic with the uranium-enriched granites and is not simply the result of later concentration of uranium from the granites by processes such as kaolinization or weathering. The investigation suggests that granites can provide an indication of primary uranium provinces as in the Hercynian province of southwest England and, hence, be of assistance in the identification of vein-type mineralization. In the Caledonides of northern Scotland, where uranium is principally associated with later faults and molasse facies sediments,

granite sampling can help to determine the enrichment processes involved and, thereby, aid the definition of economic targets. Differences in the concentration and occurrence of uranium in granites from Shetland and southwest England suggest that primary uranium provinces are the result of tectonic setting and perhaps of enrichment in Precambrian crustal rocks. (Auth)

109
Smith, W.L., and F.J. Flanagan; USGS, Washington, DC

Use of Statistical Methods to Detect Radioactivity Change Due to Weathering of a Granite. American Journal of Science 254:316-324.(1965, May)

Forty-four samples of the Conway granite were collected from the red and green phases of the rock at the Redstone, New Hampshire quarries. A large variation in radioactivity as measured by beta-counting is shown between individual samples. Inspection of the data shows that the red phase is higher in radioactivity than the green. An analysis of variance with a single variable of classification shows that the means of the fresh and weathered red phases are not significantly different, whereas a "t" test using differences between pairs of the fresh and weathered green samples shows that the means of these two sets differ significantly. From these tests and a comparison of the variances of the respective sets, it is inferred that weathering has had a significant effect on the green phase only. It has been shown, by comparing the variances of the subsets of data with the known variance of the method of measurement, that some external factor such as variations in mineralogic composition or differential leaching or adsorption may be responsible for the variations in radioactivity. (MLB)

110
Smyslov, A.A.

Distribution and Migration of Uranium and Thorium in Rocks of the Earth's Crust. Tr. Vses. Nauch.-Issled. Geol. Inst. 164:5-32.(1969)

The main characteristics of uranium and thorium distribution in sedimentary, igneous, and metamorphic rocks of various geologic formations in platform and folded regions of the earth's crust were investigated. The migration of radioelements during sediment accumulation, magmatism, and metamorphism was illustrated by a comparison of radioactivity of rocks of various geologic formations of different ages. Noticeably high redistribution of uranium and thorium in sedimentary and igneous rocks occurred during regional dynamothermal metamorphism and hydrothermal metasomatism. Migration of radioelements during regional metamorphism results in the formation of definite radiogeologic zoning of metamorphic strata in the earth's crust, changes in the forms of uranium and thorium occurrence, and increases in the heterogeneity of their distribution in upper horizons. The uranium was retained predominantly in relatively insoluble isomorphic forms in products of metamorphism in zones of amphibolite and granulite facies. In zones of greenschist facies, most of the uranium is present as mobile compounds. The presence in metamorphosed rocks of the upper part of the granitic layer of the earth's crust of large amounts of uranium capable of migration provides a possible subsequent mobilization of metals by solutions of various origins. Both increases and decreases in absolute contents of uranium and thorium and the changes in their forms are obscured during intense mineral and chemical transformation of rocks under effect of superposed magmatic alterations. In the zones of uranium, delivery among berezitized, propylitized, and other rocks, a predominant part of the uranium (more than 70 percent) is present as soluble extractable compounds. These compounds are probably related to the segregations of independent uranium minerals, gas-liquid inclusions, and other nonisomorphic forms. (Auth)(JMT)

111
Snider, J.L.; USGS, Washington, DC

Radioactivity of Some Coal and Shale of Pennsylvania Age in Ohio. TEI-404; 22 pp.(1954, July)

Channel samples of the commercially important coal beds and associated rocks in the Pottsville, Allegheny, and Monongahela formations of the Pennsylvanian system were collected in eastern Ohio. Equivalent uranium content of 0.001 percent or more was determined in the laboratory for five samples. The uranium content of the coal is less than the equivalent uranium content indicated by radioactivity measurements. None of the samples collected contain recoverable quantities of uranium in the ash. (MLB)

112
Snider, J.L.; USGS, Washington, DC

Reconnaissance for Uranium in the Indiana Coal Field. TEM-784; 26 pp.(1954, August)

A radioactivity of 0.001 or more percent equivalent uranium was found in five Indiana coal beds. The radioactive coal is local and the reserves are small. The radioactivity is in the top part of the bed in the thick coals. Most of the radioactive coal has a high percentage of ash. The black carbonaceous shale above Coal V and the Minshall coals contains about 0.006 and 0.003 percent equivalent uranium repectively, and the radioactivity appears to increase as the amount of organic matter increases in the shale. The black shale above Coal V is widespread in Indiana and adjacent states and the reserves of shale are large. (Auth)

113
Staatz, M.H., and H.L. Bauer, Jr.; USGS, Washington, DC

A Preliminary Report on Radioactive Fluorite Deposits, Thomas Range, Juab County, Utah. TEM-167A; 11 pp.(1951, December 18)

Three fluorite properties, Bell Hill, Harrisite, and Fluorite (Original Spor) group, on the west side of the Thomas Range were briefly examined for radioactivity. Most of the rock in the Thomas Range fluorite district is limestone, although there also is a wide band of quartzite in the area. Equivalent uranium percentages for the samples are: Bell Hill Property, Pit 1 - 0.25, 0.33, 0.16, and 0.19; Bell Hill Property, Pit 2 - 0.070; Harrisite Property, Open-pit - 0.084, and 0.011; Harrisite Property, Pits - 0.012; and Fluorite Group, Stope - 0.016. (PAG)

114
Staatz, M.H., N.M. Conklin, and I.K. Brownfield; USGS, Denver, CO

Rare Earths, Thorium, and Other Minor Elements in Sphene from Some Plutonic Rocks in West-Central Alaska. *Journal of Research of the US Geological Survey* 5(5):623-628.(1977, September)

Sphene ($CaTiSiO_5$) is abundant in some of the plutonic rocks of west-central Alaska, and it is one of the principal sources of thorium and rare earths in these rocks. The amounts of these elements present in sphene depends on the composition of the parent magma and the abundance of other accessory minerals that may preferentially capture these elements. Seven samples of sphene from four different areas in west-central Alaska were analyzed by a semiquantitative spectrographic method. The total rare earths content of these rocks ranged from 20,350 ppm to 39,180 ppm. The thorium content ranged from 390 ppm to 2,000 ppm. The lanthanide content in six of the seven sphenes is chiefly the light rare earths and is similar to that of crustal abundance; a seventh sphene from the Darby Mountains, however, contained above average amounts of the heavy rare earths. A comparison of the lanthanide distribution in sphene from several areas indicated that the structure of sphene will accommodate whatever lanthanides are available when the mineral crystallizes. (JMT)

115
Strahl, E.O.; Pennsylvania State University, College of Mineral Industries, State College, PA

An Investigation of the Mineralogy and Petrography of Uranium-Bearing Shales. NYO-7908; Ph.D. Thesis; 155 pp.(1958, July 14)

A total of 280 samples were analyzed for total carbon, organic carbon, aliphatic and aromatic hydrocarbon, carbonate, total iron, iron oxides, pyrite, total silicates, quartz, kaolinite, illite, amorphous silicates, uranium, molybdenum, manganese, and quartz grain size. The data obtained were analyzed using correlation and factor analysis statistics. Pyrite, organic carbon, and uranium vary together in the shales studied and depend upon reducing conditions for their concentration. Molybdenum and manganese co-precipitate in an environment characterized by the presence of carbonate minerals. The presence of carbonate is a reflection of the oxidative environment necessary to precipitate these elements. In a highly reducing environment, organic carbon and carbonate are incompatible but in a more oxidizing environment the enrichment in organic carbon is paralleled by an enrichment in carbonate. In the marine shales investigated, the amount of illite relative to the amount of kaolinite is much greater than in the continental shale. A well defined negative relationship between illite and amorphous silicates in the marine shales, and a poorly defined negative relationship between kaolinite

and amorphous silicates in the continental shales, was found. As the amount of quartz in the sediment increases, the maximum quartz grain size also increases, but the increase in grain size for a given increase in amount is more rapid in the continental shale than in the marine shales. The redox environment is the most important factor in the deposition of black shales. The rate of deposition appears to be highly interrelated with the redox environment in those cases where the rate of deposition was relatively rapid. As shown by the relationship of aliphatic to organic carbon, the organic material is uniform in character in the bituminous shales and somewhat more variable in the carbonaceous shales. (Auth)(PAG)

Thesis title is "An Investigation of the Relationships Between Selected Minerals, Trace Elements and Organic Constituents of Several Black Shales".

116

Strahl, E.O., L.A. Weiser, E. Camilli, H.D. Wright, N.M. Short, T.F. Bates, and E.N. Silverman; AEC, Washington, DC; Pennsylvania State University, College of Mineral Industries, State College, PA

An Investigation of the Mineralogy, Petrography, and Paleobotany of Uranium-Bearing Shales and Lignites: Scope A-Shales. NYO-6060; 70 pp.(1954, March 31)

Mineralogical and petrographic analysis of the Chattanooga formation resulted in the development of several important techniques, the accumulation of a large amount of quantitative data and, as a result, a clearer picture of the relationship of uranium with composition and texture as illustrated by a detailed analysis of a core from the Highland Rim area. The techniques include the perfection of nuclear emulsions for use as substrates in the electron microscope, the application of the spectrophotometer to measure the color of shale samples and the development of an x-ray method for investigating composition and texture in thin sections. Thin section point counts, alpha-track counts, electron microscope studies of bitumen and quantitative mineralogical and chemical analyses of a large number of samples have resulted in a mass of data of which the analysis is partially complete. A careful study of sixty samples from thirty-five feet of Chattanooga obtained in Core YB-4 has yielded statistically significant correlations between uranium and some of the shale constituents. The correlation is positive with respect to "blackness" of the sample, carbon, pyrite, and sulfur, and negative with quartz plus feldspar, clay and Fe_2O_3. A partial correlation of uranium, pyrite, and carbon shows that, in this core, the correlation of uranium with carbon is better when the effect of pyrite is included than when it is excluded. Since the same relationship holds in the case of uranium with pyrite, including and excluding carbon, it is apparent that the association of carbon and pyrite favors the concentration of uranium. A positive correlation of uranium with the ratio of quartz plus feldspar counted in thin section to total quartz plus feldspar together with the negative correlation of uranium with clay indicate that the black beds which contain more uranium are coarser than the gray beds. (Auth)(PAG)

117

Stuckless, J.S., C.M. Bunker, C.A. Bush, W.P. Doering, and J.H. Scott; USGS, Denver, CO

Geochemical and Petrological Studies of a Uraniferous Granite From the Granite Mountains, Wyoming. Journal of Research of the USGS 5(1):61-81.(1977, January)

The granitic rocks of the Granite Mountains are alkalic and high in silica. In this paper the rocks were divided into four units: 1) a biotitic phase which forms the dominant unit at the western end of the Granite Mountains; 2) a leucocratic phase; 3) silicified zones which crosscut the granitic rocks and form topographic highs; and 4) fractured zones which appear to have been hydrothermally altered. The uranium concentrations of the biotitic phase range between 3 and 45 ppm with an average of 9.8 ppm. The leucocratic phase has an average uranium content of 8.1 ppm, and furthermore, most samples from this phase seem to have suffered recent uranium depletion, which suggests the original uranium content was even higher. Both the biotitic phase and the leucocratic phase have anomalous thorium concentrations, but in opposite directions. The average thorium contents of the biotitic and leucocratic phases are 48.5 and 9.7 ppm, respectively. The Th/U ratio for the leucocratic phase is 1.9, and that is anomalously low even if the uranium loss is taken into account. Several mechanisms for uranium loss can be proposed. The seemingly lower uranium content of the leucocratic phase could be attributed to an early uranium loss during metamorphism or it could have been lost during a partial melting episode if this phase represents a partially assimilated xenolithic block of country

rock. More recent uranium loss for all rock types can be attributed to weathering. The relatively recent uranium loss may have been caused during the uplift of the granite when the release of overburden pressure caused near surface rocks to dilate and lose water. According to the data presented, the authors believe that an alkali granite is the best crystalline source rock for uranium, especially if it is unmetamorphosed and rapidly exposed to near surface conditions where a favorable basin exists nearby. Because of this, the granitic rocks of the Granite Mountains have been proposed as the source of uranium in the Crooks Gap, Gas Hills, and Shirley Basin uranium districts of Wyoming. (JMT)

118
Stuckless, J.S., G. Van Trump, Jr., C.M. Bunker, C.A. Bush, W.C. Hunter, and N.F. Lewis, Jr.; USGS, Washington, DC

Radiometric and Petrographic Results for Samples from Drill Holes GM-1 and GM-2, Granite Mountains, Wyoming. USGS Open-File Report 76-842; 19 pp.(1976)

The USGS has drilled two holes (GM-1 and GM-2) near the western end of the Granite Mountains to test the theory that leaching of the granite from the Granite Mountains contributed most or all of the uranium to the nearby sedimentary uranium deposits and to characterize the granite in terms of chemistry and petrography. GM-1 was terminated at a depth of 410 m and GM-2, located 20 miles north of GM-1, was terminated at 475 m. The mean concentrations of uranium and thorium are: albitized rocks: U 14.3 ppm, Th 27.8 ppm; biotite granites: U 11.5 ppm, Th 51.0 ppm; and leucocratic granites: U 8.55 ppm, Th 13.3 ppm. Standard deviations among the uranium samples are: albitized rocks, 16.3; biotite granites, 8.94; and leucocratic granites, 8.00. Preliminary evaluation of the data from the drill holes suggests that statistical evaluations of uranium, thorium, and potassium data may be sufficient to indicate uranium mobility in granite rocks. Uranium mobility is suggested by a large standard deviation relative to the mean uranium content, a non-Gaussian distribution of uranium among samples, and a failure of uranium values to correlate with either thorium or potassium contents. (PAG)

119
Surkov, Y.A., A.A. Vorobtev, V.A. Korolev, and V.D. Vilenskii

Investigation of the Isotopic Composition of Uranium Rare-Earth Minerals. Soviet Journal of Atomic Energy 9:1017-1022; Atomnaya Energiya 9:477-482.(1960)

The isotopic composition of the uranium of rare-earth minerals (orthite, xenotime, and gadolinite) was investigated for the detection of possible traces of Cm 247 in nature, by means of an ionization chamber with a multichannel analyzer of the pulse amplitudes. The results of the measurements are discussed. A method is given for the accurate calculation of distortions of the spectrum of alpha particles in ionization chambers with electron collimation. It is shown that during the investigation of samples of low intensity (0.2-1 mg of uranium), the relative content of U 235/U 238 isotopes can be measured by an alpha-spectrometric method with an error up to approximately 1 percent. (Auth)

120
Syromyatnikov, N.G., L.A. Trofimova, and M.A. Yarenskaya; Institute of Geological Sciences, Akad. Nauk Kazakh SSR, Alma-Ata, USSR

Uranium and Thorium as Indicators of the Processes of Formation of Polymetallic Sulfide Ores of the Maykain Deposit (Central Kazakhstan). Geochemistry International 8(4):533-540.(1971)

The distribution of uranium and thorium was investigated in the Maykain polymetallic sulfide deposit. Within the deposit barite-polymetallic, copper sulfide, and pyrite ores succeed one another downwards in the ore body. The pyritic ores were the first to be deposited. The copper sulfide ores were then formed by reaction between copper-bearing solutions and the pyritic ore. The polymetallic ores with barite gangue were deposited by the same solutions that deposited the copper sulfide ore after the enrichment of the solutions in zinc, lead, and barium. The principal component of these ores is sphalerite, but they also contain pyrite, chalcopyrite, tetrahedrite-tennantite, and gold and silver minerals. The pyritic ores have very low uranium contents (0.1-0.8 ppm) - four times lower, on the average than the rocks. The copper sulfide and polymetallic-barite ores from the deep zones (150-160 m) have higher uranium content than the barren rocks. At a depth of about 70 m, the same ores have relatively low average uranium contents. The thorium content of all the ores is about ten times lower than in the rocks. The Th-U ratio in the ores is very low (0.07 to 1.1). Uranium

was introduced during the second stage of mineralization, but no thorium was introduced during the entire mineralizing process, and in fact, considerable amounts of thorium must have been removed in the process. The removal of the thorium was probably accomplished by solutions of the pre-ore and pyritic stages. These solutions must have been acid, because thorium is not stable in neutral or weakly alkaline solutions. Evidently, uranium also was removed by the acid solutions, and this removal of the thorium and uranium from the rocks indicates that the process was epigenetic. The difference in the behavior of uranium during the deposition of the pyritic ores and during the later stages of mineralization may be satisfactorily explained by the existing ideas on the evolution of postvolcanic exhalations during the formation of volcanogenic-hydrothermal sulfide deposits. The early high temperature acid fluids which deposited the pyrite could not transport much uranium because they contained components which created a reducing environment. With a decrease of temperature and an increase of pH and Eh, sulfate ions appeared in the volcanic gases and the tetravalent and hexavalent uranium was able to form soluble sulfate complexes stable in the acid media. (JMT)

121

Teryakov, V.A., P.K. Vinokurov, E.I. Zheleznova, and A.I. Smirnova;

Uranium in Bauxites. Geochemistry International 12(6):173-177.(1975)

The uranium content of bauxite samples from all the major platform and geosynclinal bauxite deposits in the USSR was determined by fission tract analysis. The limit of detection by this method was 10(E-4) ppm, with a coefficient of variation of 20 percent. Bauxites are distinctly high in uranium content compared with many endogenous, exogenous, and metamorphic rocks and deposits, but the range of variation is fairly great at 2.2 to 53.9 ppm. The mean uranium content for bauxites as a whole is 12.1 ppm. There is an appreciable difference in uranium concentrations between platform and geosynclinal bauxites: 12.7 and 9.3 ppm respectively, and also for bauxites associted with parent rocks differing in composition. These differences are most pronounced for bauxites genetically related to various clay shales, basic igneous rocks, and various alkalic igneous rocks. The rather low uranium concentrations found in bauxites genetically associated wth clays and clay shales occurs because there is much less uranium in the form of resistant terrigenous materials in clays and clay shales than in igneous rocks, and more in mobile forms that is easily lost in lateritic weathering. The lower uranium contents found for bauxites in geosynclinal regions may be due to the loss of heavy uranium-bearing minerals, as in the case of many other trace elements, partly on account of the longer paths traveled by the initial aluminosilicate or bauxite material in the geosyncline. It is also quite likely that the source material for the bauxites was blown by the wind onto exposed carbonates. In that case, it is expected that the wind-borne products would have lost some heavy minerals, as has been established for volcanic ash transported by the wind. The two main reasons for the persistent association of uranium with bauxite are: 1) The uranium is inherited by the bauxite along with the relatively resistant uranium-bearing accessory minerals and 2) some of the uranium released by decomposition of unstable accessory minerals as well as by the salic and femic mineral and is present in the dispersed state, being taken up by the bauxite, especially around neutral pH in sorbed form or else as the complex $[UO_2(H_2O)_6]^{2+}$. (JMT)

122

Titayeva, N.A., V.A. Filonov, V.Ya. Ovchenkov, T.I. Veksler, A.V. Orlova, and A.S. Tyrina; Academy of Sciences USSR, Radiobiology Section, Komi Branch, Syktyvkar, USSR; Moscow University, Department of Geochemistry, Moscow, USSR

Behavior of Uranium and Thorium Isotopes in Crystalline Rocks and Surface Waters in a Cold Climate. Geochemistry International 10(9-10):1146-1151.(1974, August)

The ratios of uranium and thorium decay products can serve as good geochemical indicators for recent processes, particularly those in the supergene zone, where liquid and solid phases interact. Vigorous solid-liquid interaction is indicated by the concentrations and isotopic compositions of uranium and thorium in the water and rock in an area of the Polar Urals. Indicators of the interaction are provided by values of the U 234/U 238 and Th 228/Th 232 ratios, which for the rocks are lower than the equilibrium ones but for the waters are higher than equilibrium. The U 234/U 238 ratio allows estimation of the relative proportions of uranium and thorium escaping into the water. On the surface of the Man'Khambo granitoid intrusions, uranium is lost almost twice as fast as thorium. The series Th 232 - Ra 228 - Th

228 can be used to examine the details of current geological processes and time scales if these are not greater than 50 years. (JMT)

123
Titov, V.K., T.V. Bilibina, and G.B. Kochkin;

Uranium and Thorium in Processes of Regional Metamorphism. CONF-7205116; Radioactive Elements in Rocks, Reports of the 1st Radiogeochemical Congress, USSR, May 15-19, 1972. Novosibirsk, Publishing House, Nauka, Siberian Branch, Novosibirsk, (pp. 151-154).(1975)

The original composition of the sedimentary and sedimentary-volcanogenic rocks plays an important role in the concentration of radioactive elements in metamorphic rocks. Proportional to the increase in the degree of progressive regional metamorphism and independent of the rocks, is a decrease in the content of uranium and thorium which is associated with the intensive migration of radioactive elements, especially in respect to their transportation to the upper levels of the Earth's crust from regions of development of the epidote-amphibolite, amphibolite, and granulite facies. A relative impoverishment of uranium in easily mobile forms in derivatives of the high stages of metamorphism can be established by the comparison of rocks of the epidote-amphibloite and green shale facies. It has been demonstrated that 40 to 50 percent of the uranium in easily mobile forms is lost upon the transition from the amphibolite to the granulite facies of metamorphism. The content of thorium in metamorphic rocks also does not stay constant. In the high stages of metamorphism, thorium is transported outwardly more intensively than uranium, leading to a reduction in the Th/U ratio. The greater part of the thorium transported away from the deep zones of regional metamorphism is fixed in rocks of the amphibolite facies of metamorphism, primarily in the granitoids of these zones. There is little data presently on the migration of radioactive elements during regressive metamorphism, but the concentrations of radioactive elements in uniform rocks which have undergone an identical degree of metamorphism of the progressive and regressive stages are similar. The leading mechanism of removal of uranium and its precipitation during regional metamorphism is probably desorption and sorption of the filmy liquid phase and by infiltration of pore solutions, as well as processes that change the crystalline structures of minerals. In the history of the Earth, regional metamorphism has been one of the most powerful processes leading to significant movement of uranium and thorium, and, concerning the processes of ultra-metamorphism, has led to the formation of the radiogeological zonality of the Earth's crust. (JMT)

124
Tormo Ferrero, M.J.; Junta de Energia Nuclear, Madrid, Spain

Determinacion de Equilibrios en Minerales de Uranio por Espectrometria Alfa. Junta de Energia Nuclear 346; 33 pp.(1976)

A method for the measurement of U 234/U 238 activities is described. The separation of the uranium from the interferring elements is carried out by ionic change with anionic resine, in clorhydric-methanol-ascorbic acid medium. The method has been applied to different spanish ores in which the equilibrium state has been determined. (Auth)

125
Tugarinov, A.I., and I.B. D'yachkova;

Some Common Geochemical Characteristics of Selenium and Uranium. Vop. Prikl. Radiogel. 2:380-386.(1967)

The Se geochemistry in earth crust is controlled above all by analogy of its properties with those of Sulfur. The highest Se/S ratio, typical of sedimentary rocks in which the Se is present mostly in the form of native Se of selenides is accompanied, as a rule, by U mineralization. The mobility of Se and U under oxidizing conditions and their almost complete inert behavior in reducing media are the main geochemistry properties controlling Se and U in exogenic processes. Extraction of Se and U from rocks is possible by solutions, having sufficiently high Eh, through oxidation. The alkaline medium is the most favorable for simultaneous transfer of Se and U into the mobile state. The Se and U, migrating in surface waters, are concentrated in rocks having high reducing capacity. If, under favorable conditions (short distance from the denudation area, oxidation character of the solution, etc.), the Se reaches the sea, then, similarly to U, it is precipitated immediately and is accumulated in the continental shelf region. Absorption phenomena promote the separation of Se and S in addition to oxidation-reduction

factors. Organic substances play a large part part in the concentration of Se and U. Under hypogene conditions, the oxidation-reduction factor control to a large degree the formation of sediments of elements having changed valency in a definite sequence. (CA)

126
Varga, V.V.

Use of the Method of Contact Micro-X-Ray Photography for Studying Uranium Ores. Soviet Journal of Atomic Energy 26(1):488-491; Atomnaya Energiya 26(5):427-431.(1969, January)

Contact micro-x-ray photography was used to supplement ore data obtained by study under the microscope in reflected and transmitted light. The method separates out the uranium minerals from minerals with similar reflecting powers. Structural and textural characteristics of the ore, and grain shape are determined. Grain shape establishes whether the ore minerals are uraninite or pitchblende. X-rays are passed through 0.05 to 0.15 mm thick ore samples in direct contact with a fine-grained photo emulsion. A full-scale image of the sample is produced and then magnified in the optical microscope. (PAG)

127
Welch, S.W.; USGS, Washington, DC

Radioactivity of Coal and Associated Rock in the Coal Fields of Eastern Kentucky and Southern West Virginia. TEI-347A; 38 pp.(1953, June)

A reconnaissance study was made of radioactivity of coal and associated rock in the coal fields of eastern Kentucky and Logan and Mingo counties, West Virginia. Sixty-one localities were visited and 98 samples, 90 of coal and two each of carbonaceous shale, marine shale, flint clay, and dike rock, were collected. The results showed the coal to have little or no radioactivity - 0.000 to 0.001 percent equivalent uranium, and the other rock sampled to have slight radioactivity - about 0.002 percent equivalent uranium. No correlation between radioactivity and stratigraphic position nor between radioactivity and structural relationship was detected. (PAG)

128
Welch, S.W.; USGS, Washington, DC

Radioactivity of Coal and Associated Rocks in the Anthracite Fields of Eastern Pennsylvania. TEI-348; 31 pp.(1953, April)

A reconnaissance of coal and associated rock was made in the anthracite fields of eastern Pennsylvania. Forty-six localities were visited and 153 samples, 150 of coal and 3 of shale, were collected. The radioactive content of the rocks ranged from background to 0.001 percent equivalent uranium in the coal and from 0.001 to 0.003 percent equivalent uranium in the shale. (Auth)

129
Williamson, A.N.; US Army Engineer Waterways Experiment Station, Vicksburg, MS

Gamma-Ray Measurements to Evaluate Soil Properties. Remote Sensing of Environment, Proceedings of the Fifth Symposium, Ann Arbor, Michigan, April 16-18, 1968. Willow Run Laboratories, Ann Arbor, Michigan, (pp. 737-746), 946 pp.(1968, September)

Gamma radiation from soil samples obtained from nearly all of the states and Puerto Rico was measured in the laboratory and the results were analyzed to evaluate the use of gamma-ray measurements to convey information about the soil. The data were arranged according to land usage and into classifications according to the following systems: geological material type, geological material age, USDA Great Soil Group, and USDA Soil Order based on the Seventh Approximation. By plotting the gamma-ray photopeak count ratios of Th 232/K 40 versus U 238/K 40 and the normalized photopeak counts for U 238 and Th 232 versus sand content, it was shown that the criteria for separating the soils were either too broad or not significant to the gamma-ray emissive characteristics of soil. However, the data showed that the Th 232 and U 238 photopeak counts depended upon the particle size distribution in the soil and indicated that gamma-ray measurements can provide a qualitative indication of sand content. (Auth)

130
Yamamoto, T., E. Yunoki, M. Yamakawa, and M. Shimizu

Environmental Contamination by Uranium, Part 3: Effects of Carbonate Ion on Uranium Adsorption to and Desorption from Soil. Journal of Radiation Research 14:219-224.(1973)

Adsorption of uranium on soils and its desorption from uranium-adsorbed soils in the presence of carbonate ion were examined by using three kinds of soils: alluvial soil, sandy soil and volcanic ash soil. The absorption ratio of uranium for each soil was approximately 100 percent for the mixtures of uranyl (1 to 50 ugU/ml) and carbonate solutions (4.3 to 109 ugCO3(E-2)/ml). In the uranium adsorbed soil (7.1 to 500 ugU/g air-dried soil) with carbonate ion (4.3, 43.4 ug/ml), the desorption ratio of uranium for each soil was low (0.09 to 1.2 percent). The adsorbed soils with stream water were probably similar to those with carbonate solution. (Auth)

131
Yeliseyeva, O.P., I.D. Ryabchikov, and N.A. Bogatyreva; Academy of Sciences USSR, Moscow, USSR; Institute of Geology of Ore Deposits, Petrography, Mineralogy and Geochemistry, Moscow, USSR; Moscow State University, Moscow, USSR

On the Types of Distribution of Uranium in Accessory Zircon. Geochemistry International 11(5):960-968.(1974)

The behavior of uranium in crystals of accessory zircon from granitoids of Middle Asia and Northern Kazakhstan was investigated by the fission tract method. Four types of uranium distribution in the zircon was revealed by this study: uniform, concentrated, zonal, and superimposed distribution in fractures. The different patterns and details of distribution reflect the internal structure of crystals. Concentrations of uranium occur in the cores of the crystals, in growth zones, in some inclusions, and in fine fractures. Uranium distribution in zircons with homogeneous structure is uniform. The difference in the time of crystallization of the zircons during the emplacement of granitoid massifs may be responsible for the different uranium distributions. An analysis of the data based on the theory of behavior of isomorphous admixtures during crystallization of melts shows that there are several types of distribution of uranium in zircon crystals, corresponding to: a) the case when U and Zr concentrations become uniformly distributed through the melt by diffusion only, resulting in impoverishment of the core in uranium, uniform distribution of uranium through the main part of the crystal, and uranium enrichment of the outer zone; b) the occurrence of periods of intensive stirring of the melt and destruction of the diffusion zone near the growing zircon crystals resulting in repeated alterations of uranium-poor and uranium-rich zones beginning at the core with low uranium content; c) formation of new zircon crystals within the diffusion zone surrounding earlier crystals whereupon the cores of the crystals are relatively enriched in uranium. (JMT)

132
Yermolayev, N.P.; Vernadskiy Institute of Geochemistry and Analytical Chemistry, Academy of Sciences of the USSR, Moscow, USSR

Physico-Chemical Principles of the Redistribution of Radioactive Elements During the Progressive Metamorphism of Rocks. CONF-7205116; Radioactive Elements in Rocks, Reports of the 1st Radiogeochemical Congress, USSR, May 15-19, 1972. Novosibirsk, Publishing House, Nauka, Siberian Branch, Novosibrisk, (pp. 140-146).(1975)

The most important reactions which characterize the metamorphic facies upon an increase in temperatures and pressures occur with the loss of water and carbon dioxide. Under conditions of release of significant amounts of water and carbon dioxide from the rock (a characteristic of the initial stages of metamorphism) uranium is desorbed most easily. Proportional to the extension of progressive metamorphism and the decrease in water and gas yield of the rock, the role of recrystallization and liberation of radioactive elements increases in comparison with the role of surface phenomena. In connection with this, the relative yield of thorium from the rock also increases. The processes of migmatization and granitization are accompanied by the dissolving of a number of mineral carriers of uranium and thorium and the transport out of radioactive elements at the initial stage of ultrametamorphism together with certain rock-forming components (Fe, Ti, Mg). These processes, which are accompanied by the intake of alkali and SiO2, and the migration out of bivalent bases, can be characterized as the noncarbonate form of uranium and thorium transport, inasmuch

as by the beginning of ultrametamorphism, carbon dioxide has been almost completely eliminated from the rocks. Prior to encountering the carbonate medium, uranium is capable of migrating in the silicate form. (JMT)

133
Yermolayev, N.P.; Vernadskiy Institute of Geochemistry and Analytical Chemistry, Academy of Sciences of the USSR, Moscow, USSR

Uranium and Thorium in Regional and Contact Metamorphism. Geochemistry International 10(3-4):418-423.(1974, May)

Uranium begins to be mobilized and lost from rocks at low grades of regional metamorphism and with progressive contact metamorphism. As the grade of progressive metamorphism increases, thorium also becomes mobilized, and the Th/U ratio gradually falls during rock transformation as the temperature and pressure increases. Extensive progressive metamorphism of sediments and volcanics causes the products in the initial stage of ultrametamorphism to have extremely low concentrations of uranium and thorium because both elements are carried into the upper part of the Earth's crust along with displaced water and carbon dioxide. This tendency persists until anatexis occurs during ultrametamorphism. High-grade ultrametamorphism is accompanied by mobilization of uranium and thorium, together with the production of melts with elevated radioactivity. The resulting crystalline rocks play a decisive role in the emplacement of the highly radioactive granitic layer of the Earth's crust. The retrograde stage of regional and contact metamorphism represents a transitional link in the geochemistry of uranium and thorium from metamorphic ore formation to hydrothermal. Retrograde metamorphism evolves as regards uranium and thorium from regional radioelement migration to local metasomatic accumulation of radioelements. (Auth)(JMT)

134
Yermolayev, N.P.; Vernadskiy Institute of Geochemistry and Analytical Chemistry, Academy of Sciences of the USSR, Moscow, USSR

Processes of Redistribution and Extraction of Uranium in Progressive Metamorphism. Geochemistry International 8(4):599-609.(1971)

There is a regular increase in the loss of uranium from sediments as the grade of progressive metamorphism increases. The three types of extraction mechanisms for uranium in metamorphism are: (1) recrystallization; (2) desorption of uranium into film liquid and carbonate solutions in the pores; and (3) dissolution of uranium carrier minerals. Sediment differentiation dominates uranium redistribution in rock recrystallization. Uranium is least likely to be redeposited with substances having little affinity with uranium hydroxide and uranium ions (quartz and feldspars). Minerals of Fe, Ti, Zr, and the rare earths actively take up uranium from the solution of recrystallization. The distribution parameters for the rock uranium concentration show a trend with the grade of metamorphism that allow one to reconstruct the distribution along the line of progressive metamorphism and to distinguish concentrations genetically related to superimposed processes. Water-salt systems have been used to consider the mechanisms of uranium redistribution and extraction in rocks. These are of general significance and can be applied to the behavior of some other heavy elements in metamorphism. (JMT)

135
Zverev, V.L., A.I. Spiridonov, and V.M. Shvets; Geological Exploration Institute, Moscow, USSR

On the Balance of Uranium in the Ocean. Geochemistry International 13(3):88-93.(1976)

The U 234/U 238 isotope ratio in ocean water is constant and equals 1.15. This ratio is independent of geographic latitude, depth of the ocean and concentration of uranium in the water. The bottom sediments of the ocean give up not less than 25 percent of their uranium. A consequence of this process is enrichment of interstitial waters of the sediments in U 234 relative to sea water. Although these sediments are an important source of uranium in ocean waters, the main mass of uranium (approximately 10(E+4) tons/year) is brought in by rivers. Submarine volcanic activity also contributes uranium to the ocean, although this contribution was probably greater in the past. Eolian erosion also plays a role in the uranium content of oceanic waters, as does material entering the earth from cosmic space. The latter's contribution is insignificant. These factors determine not only the content of uranium in ocean water, but also its isotopic composition. The balance of uranium in the ocean is predominantly regulated by the activity of organisms. (JMT)

EXPLORATION

136
Geodata International, Incorporated, Dallas, TX

The Development of a USERDA Dynamic Test Range for Calibration of Airborne Gamma Radiation Measuring Systems. GJBX-46(77), Vol. 1; 72 pp.(1976, November 17)

The Lake Mead Dynamic Test Range was developed for the purpose of providing a surface region over which airborne gamma radiation measuring systems may be calibrated for measurement of surface concentrations of eU, eTh, and K. One hundred and seventy-one 2000 g soil samples were assayed radiometrically for eU, eTh, and percent K; sixty samples were analyzed for U and Th by neutron activation analysis; and potassium was assayed by chemical methods. Results are: neutron activation analysis: U 2.33 ppm, Th 11.83 ppm; chemical analysis: K 2.48 percent; and radiometric analysis: eU 2.88 ppm, eTh 11.8 ppm, K 2.45 percent. Field surface radiometric assay averages are: eU 2.77 ppm, eTh 11.62 ppm, and K 2.44 percent. Effective surface concentrations from the airborne survey are: eU 2.62 ppm, eTh 11.56 ppm, and K 2.53 percent. (PAG)

137
Geodata International, Incorporated, Dallas, TX

Lake Mead Dynamic Test Range for Calibration of Airborne Gamma Radiation Measuring Systems. GJBX-46(77), Vol. 2; 38 pp.(1977)

Six sets of data at altitudes of 200, 400, 600, 800, 1000, and 1200 feet from the Lake Mead Dynamic Test Range are presented. The six sets of data give radar surface altitude, eTh in ppm, eU in ppm, K in percent, BiAir, total magnetic field, total count greater than 400 Kev, eU/eTh, eTh/K. (PAG)

Gamma radiation data constitutes the report.

138
International Atomic Energy Agency, Vienna, Austria

Exploration for Uranium Ore Deposits. CONF-760316; Proceedings of a Symposium, Vienna, March 29-April 2, 1976. International Atomic Energy Agency. Vienna; 807 pp.(1976, August)

The papers in this symposium describe developments in the existing exploration techniques, proposals for future research and development and case histories of exploration programs. Fourteen techniques used over the last 30 years are identified and their appropriate application, advantages and limitations are summarized and the possibilities of their further development discussed. (PAG)

Select papers from the symposium are input as separate records.

139
Texas Instruments, Inc., Dallas, TX

Feasibility Study for an Airborne High-Sensitivity Gamma-Ray Survey of Alaska: Phase 2 (Final) Report - 1976-1979 Program. GJO-1646; 292 pp.(1975)

The study constitutes a determination of the extent to which it is feasible to use airborne, high-sensitivity gamma-ray spectrometer systems for uranium reconnaissance in Alaska, and specification of a preliminary plan for surveying the entire state in the 1975-1979 time frame. Phase I included the design of a program to survey the highest priority areas (11 quadrangles in 1975). Phase II includes the design of alternative programs to cover the remaining 128 quadrangles using either a DC-3 and a Bell 205A helicopter or a Helio Stallion STOL aircraft and a Bell 205A helicopter during 1976-1979. The flying schedule was determined by geologic priority (anticipated uranium potential), predicted weather conditions, terrain characteristics, and logistical considerations. Possible new system development in both airborne gamma-ray spectrometers and in ancillary equipment are outlined. The DC-3/205A alternative program comprises 40,500 flight line miles by DC-3 and 60,046 flight line miles by Bell 205A helicopters. The DC-3 survey is completed in the first two years and the helicopter survey continues for all four years. All first priority quadrangles and most of the second priority quadrangles will have been surveyed by the end of 1977. The Helio Stallion/205A alternative program comprises 57,762 flight line miles by Helio Stallion and 42,834 flight line miles by Bell 205A. The program includes three complete years of STOL aircraft surveying and uses one helicopter for four years. The program would be 98.5 percent complete at the end of 1978.

Simultaneous studies complementary to the airborne survey include: study of local snow cover using satellite imagery as an aid in detailed survey planning, photogeologic mapping of unmapped areas for airborne data evaluation using available photography and satellite imagery, a thorough study of the effects on AGR data of atmospheric inversions in trapping radon below the inversion layer, and the development of methods to eliminate the problem, and use of other methods such as geochemical studies, radon measurements or "spot" radiometric studies over the "unsurveyable" parts. A set of specifications for the entire survey program is outlined using the approaches most likely to be realized. (Auth)(PAG)

140
S.M. Stoller Corporation, New York, NY

Uranium Exploration Activities in the United States. EPRI EA-401; 170 pp.(1977, June)

Domestic uranium exploration activities, both past and present, are reviewed and analyzed in the study, which had three objectives: (a) to examine the nature of the experience accumulated to date; (b) to summarize the information presently available to utilities on the scope and nature of the ongoing exploration effort; and (c) to address a key question-namely, what changes are necessary in the current data-reporting system to enable utilities to make meaningful judgments of current progress and, relatedly, of the adequacy of current effort? The historical review, covering the period from the late 1940's through 1975, includes detailed chronologies of market incentives, of major discoveries in the United States, classified by type (e.g., primary or trend), and of mill closures, accompanied by explanations of the attendant circumstances. The changing state of knowledge of the domestic uranium resource environment is reviewed, and an analysis is made of the results and difficulties surrounding effort-yield correlations and trends. The report presents an assessment of the adequacy of ongoing activities. The study concludes that substantial increases in find rates are required over the near term in order to meet uranium requirements from domestic sources in the 1986-1995 period. Recommendations are made for finer-structure reporting by ERDA of supply industry activities which is seen as a vital ingredient to an improved two-way flow of information between producers and the utility industry. (Auth)(MLB)

This is a companion report to EPRI EA-400.

141
AEC, Grand Junction Office, Production Evaluation Division, Grand Junction, CO

USAEC Airborne Radiometric Reconnaissance in Arizona, California, Nevada and New Mexico, 1953 to 1956. RME-147; 73 pp.(1966, August)

The report contains sixty-four airborne anomaly maps of parts of Arizona, California, Nevada, and New Mexico. An airborne radioactivity survey map of the western United States is also included. (PAG)

This report contains only maps.

142
AEC, Grand Junction Office, Production Evaluation Division, Grand Junction, CO

USAEC Airborne Radiometric Reconnaissance in Arkansas, Colorado, Montana, Texas and Utah, 1952 to 1955. RME-148; 59 pp.(1966, August)

The report contains fifty airborne anomaly maps of parts of Arkansas, Colorado, Montana, Texas, and Utah. An airborne radioactivity survey map of the western United States is also included. (PAG)

This report contains only maps.

143
Oak Ridge Gaseous Diffusion Plant, Uranium Resource Evaluation Project, Oak Ridge, TN

Hydrogeochemical and Stream Sediment Reconnaissance Basic Data for Green Bay NTMS Quadrangle, Wisconsin. GJBX-93(78); K/UR-102; 151 pp.(1978, June 15)

Field and laboratory data are presented for 695 groundwater samples, 546 stream sediment samples, and 401 stream water samples. There are two areas in the Green Bay Quadrangle in which regionally high uranium values are reported: the Wausau complex and the Wolf River Batholith. Twelve radioactive mineral localities have been identified in the Wausau complex in Marathon County. Associated minerals are reported as thorogummite, hematite, zirconium, and quartz lenses. The Wolf River Batholith covers a large portion of the central Green Bay Quadrangle. Most occurrences of uranium in Penokean and

Elsonian granite and gneiss are in ferromagnesian zones in predominately quartzose feldspathic gneiss. The high uranium concentrations found are in samples which are moderately coarse grained and porphyritic, containing visible fluorite and more than average biotite. Studies show a thorium/uranium ratio of 5:1 in the highest grade samples. No samples were found to contain more than 0.08 percent U3O8. Anomalous uranium concentrations occur in stream sediments from Marathon, Wood, and Portage Counties; however, other associated variables suggest that the uranium is associated with refractory minerals which are less favorable for commercial potential. Concentrations of uranium above the 85th percentile are also found in Waushara, Winnebago, Outagamie, and Shawano Counties within the area of Cambrian sandstone and Prairie du Chien outcrop. Groundwater and stream water representing the Sinnipee and Ancell Rock Groups, and the Richmond and Silurian Formations are characterized by high conductivity, calcium, magnesium, sulfate, total alkalinity, and pH, but moderate to low concentrations of uranium. Greater than 85th percentile concentrations of uranium in all sample types define an area of about 2,000 sq km in the central and north central portions of the survey area as the most probable area for potential uranium mineralization within the quadrangle. Bedrock of the area includes granitic and monzonitic batholiths of Precambrian age. (PAG)

Appendix A contains groundwater data, Appendix B contains stream sediment data, Appendix C contains stream water data, and Appendix D contains field and laboratory data.

144
Oak Ridge Gaseous Diffusion Plant, Uranium Resource Evaluation Project, Oak Ridge, TN

Hydrogeochemical and Stream Sediment Reconnaissance Basic Data for Iron Mountain NTMS Quadrangle, Michigan, Wisconsin. GJBX-97(78); K/UR-106; 130 pp.(1978, June 22)

Results from 479 groundwater samples, 369 stream sediment samples, and 389 stream water samples delineate several areas which appear favorable for possible uranium mineralization within the Iron Mountain Quadrangle. Uranium concentration above the 85th percentile occur in the southern third and the northeast corner of the quadrangle. Areas associated with the Wolf River Batholith and the McCaslin units are the most prominent. The McCaslin Formation is composed of a basal quartz pebble conglomerate, with pyrite occurring in the matrix, overlain by a thicker quartzite. Small supergene uranium showings, usually developed on the Red River Quartz Monzonite of the Wolf River Batholith, occur as thorogummite nodules. Thorogummite also occurs as an accessory mineral in the wall zone of the Stettin Syenite of the Wolf River Batholith. Other notable areas are present in the northeast and the southwest corners of the quadrangle. Both of these areas are dominated by Precambrian igneous and metamorphic rocks, which are quite variable in composition. (PAG)

145
Oak Ridge Gaseous Diffusion Plant, Uranium Resource Evaluation Project, Oak Ridge, TN

Hydrogeochemical and Stream Sediment Reconnaissance Basic Data for Eau Claire NTMS Quadrangle, Wisconsin, Minnesota. GJBX-94(78); K/UR-103; 148 pp.(1978, June 15)

Field laboratory data are presented for 565 groundwater samples, 680 stream sediment samples, and 667 stream water samples. Statistical and areal distributions of uranium and other possible uranium-related variables are given. A generalized geologic map of the survey area is provided and pertinent geologic factors which may be of significance in evaluating the potential for uranium mineralization are briefly discussed. Based on results from groundwater, stream sediment, and stream water samples, the most favorable area for uranium mineralization within the Eau Claire Quadrangle is located in the northeast corner of the quadrangle. This area is dominated by undifferentiated igneous and metamorphic rocks, Precambrian in age and felsic in composition. Another area delineated by results from groundwater and stream water data is located in the southwest corner of the quadrangle. The dominant geologic unit in the area is the Prairie du Chien Group which consists primarily of dolomite. The high values of uranium occurring in this area are attributed to the high dissolved solid content of the water due to the dissolution of the dolomite. (Auth)

146
Oak Ridge Gaseous Diffusion Plant, Uranium Resource Evaluation Project, Oak Ridge, TN

Hydrogeochemical and Stream Sediment Reconnaissance Basic Data for Rice Lake NTMS Quadrangle, Wisconsin. GJBX-95(78); K/UR-104; 145 pp.(1978, June 22)

Field and laboratory data are presented for 518 groundwater samples, 540 stream sediment samples, and 533 stream water samples. Statistical and areal distributions of uranium and other possibly uranium-related variables are displayed. A generalized geologic map of the survey area is provided and pertinent geologic factors which may be of significance in evaluating the potential for uranium mineralization are briefly discussed. Greater than 85th percentile concentrations of uranium in all sample types define areas totaling approximately 2,500 sq km in the south central and southeast portions of the survey area as the most probable areas for potential uranium mineralization within the quadrangle. Bedrock consists of undifferentiated Precambrian igneous and metamorphic rocks. Two geographic trends are defined within this area which may be controlled by both bedrock and structure. Areas of anomalous uranium concentrations also occur in groundwater and stream waters in west central and southwest portions of the Rice Lake Quadrangle. These occurrences are in Upper Cambrian Sandstone and total approximately 125 sq km. Groundwater and stream water samples in areas of high-uranium values show correlations with calcium, magnesium, and total alkalinity in both Precambrian and Cambrian bedrock. (Auth)

147
Oak Ridge Gaseous Diffusion Plant, Uranium Resource Evaluation Project, Oak Ridge, TN

Hydrogeochemical and Stream Sediment Reconnaissance Basic Data for Oklahoma City NTMS Quadrangle, Oklahoma. GJBX-109(78); K/UR-107; 125 pp.(1978, July 25)

Field and laboratory data are presented for 812 groundwater samples and 847 stream sediment samples. Based on the results from groundwater sampling, the most promising formations for potential uranium mineralization in the quadrangle are the Permian Bison, Purcell-Salt Plains-Kingman, Fairmont, Dog Creek, Chickasha, Duncan, and Cedar Hills Formations. These units are characterized by relatively high average concentrations of uranium, conductivity, arsenic, calcium, lithium, molybdenum, and sulfate. In addition, groundwaters from the Pennsylvanian Oscar Formation are characterized by values above the 85th percentile for uranium, conductivity, the uranium/sulfate ratio, arsenic, and vanadium. Results of stream sediment sampling indicate that the most promising formations for potential uranium mineralization include the same Permian Formations as indicated by groundwater sampling in an area where these formations crop out north of the North Canadian River. Stream sediment samples from this area are characterized by concentrations above the 85th percentile for uranium, thorium, arsenic, lithium, manganese, and vanadium. (Auth)(PAG)

148
Oak Ridge Gaseous Diffusion Plant, Uranium Resource Evaluation Project, Oak Ridge, TN

Hydrogeochemical and Stream Sedimer Reconnaissance Basic Data for Plainvie NTMS Quadrangle, Texas. GJBX-92(78), K/UR-101; 135 pp.(1978, June 8)

Field and laboratory data are presented for 969 groundwater samples and 571 stream sediment samples. Results from groundwater samples indicate that at least two distinctly different types of groundwater occur in the Plainview Quadrangle. One is associated with the Permian units and is characterized by high conductivity values with high concentrations of uranium, molybdenum, and sulfate. The other is associated with the Ogallala Aquifer System and is characterized by high alkalinity values and high concentrations of arsenic, lithium, molybdenum, selenium, and vanadium. Results from stream sediment samples indicate that two distinct associations between uranium and other elements occur in the Plainview Quadrangle. An association consists of high soluble uranium values accompanied by relatively low total-to-soluble uranium ratios with high values for vanadium, and to a lesser extent, arsenic and selenium. This association is indicative of the type of secondary mineralization expected in sedimentary units which is related to commercial potential. The other association consists of high values of total uranium and high total-to-soluble uranium ratios with high values for barium, manganese, titanium, thorium, and zirconium. This association is indicative of heavy and resistate mineral suites which are less favorable for commercial potential. (Auth)(PAG)

149
Oak Ridge Gaseous Diffusion Plant, Uranium Rescurce Evaluation Project, Oak Ridge, TN

Hydrogeochemical and Stream Sediment Reconnaissance Basic Data for San Antonio NTMS Quadrangle, Texas. GJBX-96(78); K/UR-105; 149 pp.(1978, June 22)

Field and laboratory data are presented for 781 groundwater samples, 541 stream sediment samples and 331 stream water samples. Based on results from groundwater and stream water samples, extensive areas within the San Antonio Quadrangle are producing water from saline environments. These areas are located southeast of the Balcones Escarpment. These high groundwater values for uranium are associated mainly with the Cenozoic sediments of the Midway and Wilcox Groups, the Carrizo Formation, and the Quaternary alluvial fan and fluviatile deposits. Many groundwater samples having uranium concentrations above the 85th percentile are in proximity to oil and gas fields and near-surface lignite deposits. High surface water values for uranium in this area are associated with Upper Cretaceous units within the Balcones Fault Zone, the Midway and Wilcox Groups and the Quaternary alluvial fan and fluviatile terrace deposits. An area where concentrations are very close to the 85th percentile is located in the north-central portion of the survey area. Basins in this area drain from the Glen Rose Formation. Results from stream sediment samples indicate that high uranium values occur predominantly in the southeast corner of the quadrangle. The high values of uranium that occur in this area are associated with the Tertiary Formations, most notably the Carrizo Sand of the Claiborne Group. High uranium values associated with the Carrizo Sand appear to be related to heavy and/or resistate minerals. (PAG)

150
Oak Ridge Gaseous Diffusion Plant, Uranium Resource Evaluation Project, Oak Ridge, TN

Procedures Manual for Groundwater Reconnaissance Sampling. GJBX-62(78); K/UR-12; 57 pp.(1978, March 31)

This manual directs and coordinates field operations for the Oak Ridge Gaseous Diffusion Plant's hydrogeochemical uranium resource evaluation project. Site selection, sample collection, and instructions for completing forms and entering sites on maps are contained in the appendices of the manual. (PAG)

151
University of California, Lawrence Livermore Laboratory, Livermore, CA

Hydrogeochemical and Stream-Sediment Survey (NURE) Western United States - Quarterly Progress Report - January 1 - March 31, 1976. UCID-16911-76-1, Rev. 1; 17 pp.(1976)

The major accomplishments of the NURE project in the Western United States during the quarter, January 1-March 31, 1976 were as follows: (1) the completion of a number of major studies of analytical procedures and methods, and the commitment to a neutron activation multi-element analytical system whose capacity will reach 20,000 to 30,000 samples per year before the end of the first quarter of FY 1977, tripling current capacity; (2) the design of the first regional survey and the preparation of draft contracts for its execution; (3) the continuation of studies of analytical methods and sample processing using samples of sediments collected during the pilot studies; and (4) the completion of the detailed structure of the site and sample acquisition data base. (JMT)

152
Aamodt, P.L.; Los Alamos Scientific Laboratory, Los Alamos, NM

Uranium Hydrogeochemical and Stream Sediment Reconnaissance in Lincoln and Flathead Counties, Northwest Montana. LA-6652-MS; GJBX-48(77); 41 pp.(1977, May)

Water and water-transported sediment samples were collected from 1781 locations in northwestern Montana. The 3409 samples were analyzed for total uranium-the waters by fluorimetry and the sediment (and those waters with greater than 10 ppb uranium) by delayed-neutron counting methods. The 1684 water samples were collected from five sources, including 1582 streams, 44 natural ponds, 41 springs, 14 artificial ponds, and 3 wells. Of the 1725 sediment samples, 1542 were from active streams, 87 were from dry streams, 41 from wet natural ponds, 38 from flowing springs, 14 from wet artificial ponds, and 3 from other sources. The uranium concentrations measured in

the waters range from undetectable (less than 0.2) ppb to 173.6 ppb, but average only 0.66 ppb. The low uranium concentrations in the waters of this area are thought to be due primarily to a general lack of readily soluble uranium and dilution with spring runoff. The uranium content of the sediment samples range from 0.5 ppm to 52.2 ppm and average 4.56 ppm. A distinct correlation between the high uranium in sediment and epithermal and mesothermal veins associated with nearby faults and folds is evident at several locations. A correlation between high uranium in water and high uranium in sediment is evident at only a single location, that of a flowing spring. The generally low uranium concentrations in water and moderate concentrations in sediment seem to indicate that most of the uranium that does exist in this area is bound up in resistant minerals. Twenty-six isolated high-uranium sediment locations were detected. (Auth)(PAG)

Raw data are included in the appendices.

153
Aamodt, P.L., D.E. Hill, and R.R. Sharp, Jr.; Los Alamos Scientific Laboratory, Los Alamos, NM

Uranium Hydrogeochemical and Stream Sediment Reconnaissance Data from the Area of the Noatak and Portions of the Baird Mountains and Ambler River Quadrangles, Alaska. GJBX-87(78); LA-6846-MS; 74 pp.(1978, May)

A total of 876 natural water and 861 bottom sediment samples were collected at a nominal density of one location each 23 square kilometers from streams and small lakes throughout the Noatak quadrangle, the southern two-thirds of the Baird Mountains quadrangle, and in the southwest corner of the Ambler River quadrangle. Total uranium was measured in the waters by fluorometry and in the sediments by delayed-neutron counting. The uranium concentrations of these waters ranged from below the detection limit (less than 0.01 ppb) to 8.38 ppb. Clusters of high-uranium waters occur at several locations in association with Paleozoic sedimentary rocks and apparently with Cretaceous granite in the Baird Mountains. The uranium contents of the sediments ranged from a low of 0.3 ppm to a high of 34.0 ppm. The data indicate that certain areas underlain by Paleozoic sedimentary rocks and granitic intrusives within the Baird Mountains and a quartz-pebble conglomerate in the Waring Mountains may warrant more detailed field investigations. (PAG)

The following appendices are included in the report: Appendix A - Standard Field and Analytical Procedures; Appendix B - Listings of Field Data and Uranium Concentrations for Water Samples; Appendix C - Listings of Field Data and Uranium Concentrations for Sediment Samples; Appendix D - Code to Data Listings; Appendix E - Dissolved Oxygen in Waters.

154
Alexander, P.; Bendix Field Engineering Corporation, Grand Junction, CO

Nuclear Techniques in Uranium Exploration and Assay. Instrumentation in the Aerospace Industry 22:453-462.(1976)

The paper presents a brief survey of various nuclear methods utilized for uranium exploration and assay. Methods surveyed include: gross gamma ray counting, gamma ray spectral analysis, and active neutron interrogation. The potential use of nuclear techniques by the Uranium Industry may be classified into the following four areas: (1) location of uranium ore bodies or areas of high favorability for ore body location, (2) analysis of the ore grade and ore body extent once located, (3) mining applications such as ore grade control, vein geometry, rock support, and (4) metallurgical applications such as on line and in-situ process and enrichment control. The paper deals with the present state-of-the-art and future technology development plans in the first two areas. Specifically a brief summary of airborne, ground surface, and subsurface methods for location of uranium ore deposits and analysis of the ore grade and physical extent is presented together with a description of the strengths and weaknesses of the instrumentation available for the applications mentioned. (MLB)

155
Allan, R.J., and K.A. Richardson; Canada Geological Survey, Energy, Mines and Resources Department, Resource Geophysics and Geochemistry Division, Radiation Methods Section, Ottawa, Ontario, Canada

Uranium and Potassium Distribution by Lake-Sediment Geochemistry and Airborne Gamma-Ray Spectrometry: A Comparison of Reconnaissance Techniques. CIM Bulletin 67(746):109-120.(1974, June)

Two reconnaissance techniques were used to determine uranium and potassium distribution

over a 47,000-sq.-km area of the northwestern Canadian Shield, and the results from the two surveys are compared. The surveys, using lake-sediment geochemistry with sample sites at 5-km intervals and airborne gamma-ray spectrometry with flight lines 5 km apart, were carried out during the summer of 1972. The boundary between the Proterozoic Bear and the predominantly Archean Slave structural provinces of the Canadian Shield roughly bisects the survey area. In turn, the Bear Province area is roughly bisected by the north-trending Wopmay Fault. The two surveys produced generally similar results. Both show the lowest levels of uranium and potassium in the Slave Province, and in the Bear Province area east of the Wopmay Fault. The highest uranium and potassium concentrations are found in the area of the Bear Province to the west of the Wopmay Fault, coincident with, and occurring in, the Great Bear Batholith. The results of both surveys indicate the position of the Wopmay Fault by a distinct decrease in uranium and potassium concentrations. Neither survey shows a significant change at the Bear-Slave structural province boundary. The coherent patterns of uranium and potassium distribution, arrived at independently by each technique, indicate a considerable regional continuity in the distribution of these two metals in this aprt of the Precambrian crust. In view of the fundamental differences in the methodology employed by the two techniques, the degree of coincidence of the element distribution patterns is striking. Such agreement is evidence that both methods are measuring closely the real regional distribution pattern for uranium and potassium. Thus both methods are suitable for reconnaissance mapping of uranium and potassium, but the airborne gamma-ray technique is generally applicable to all kinds of terrain (excepting mountainous), whereas the geochemical technique, as used here, has been specifically developed for areas with numerous lakes, i.e. the Canadian Shield. The reconnaissance surveys to determine uranium and potassium distribution were carried out by the two techniques at approximately the same cost per unit area. For a small additional cost, provided no extra flying is done, an airborne spectrometry survey could be expanded to incorporate other airborne geophysical measurements. Also for a small additional cost, once the samples have been collected, a regional lake-sediment geochemical survey could produce maps of the distribution of many other elements. (Auth)

156

Allen, J.W.; Bendix Field Engineering Corporation, Grand Junction, CO

Development of a Portable Radon Detection System. GJBX-50(76); 55 pp.(1976, September)

The report describes a program conducted to develop and field test a prototype system for measuring radon from soil gas and water. The system was to be compact, battery-operated, and incorporate a commercial portable scaler. Previous reports and laboratory tests indicated that a Lucas Chamber alpha detection system could provide adequate sensitivity in a portable configuration. A prototype system was designed and constructed, utilizing standard commercial components, to provide a fieldworthy unit for testing the system concepts. Laboratory and preliminary field tests of this unit indicate that it can detect anomalous radon levels of less than 10 pico Curies per liter (pCi/l) in soil gas and ground water. (MLB)

157

Archer, B.J., Jr.; AEC, Grand Junction Office, Grand Junction, CO

Reconnaissance for Uranium in the Toadlena Area, San Juan County, New Mexico. TM-99; 15 pp.(1957, January)

A uranium reconnaissance in the Toadlena area, New Mexico, included an airborne scintillation survey, ground checking of radioactive anomalies discovered from the airborne survey, ground mapping and radiometric checking of 34 miles of sedimentary rock outcrops, and examination of all areas of apparent intensive alteration of structural displacement. Only one area of anomalous radioactivity was considered worthy of detailed work. It is a weakly mineralized black sand deposit 2 to 8 feet wide, extending 1750 feet along the steeply dipping Gallup sandstone of the Mesaverde group. The deposit is not of apparent importance as a source of uranium. (Auth)(MLB)

158

Arendt, J.W.; Union Carbide, Oak Ridge Gaseous Diffusion Plant, Oak Ridge, TN

Hydrogeochemical and Stream Sediment Reconnaissance Program in Central United States, First Quarter FY 1977, October 1, 1976 - December 31, 1976. GJBX-42(77); K/UR-3, Part 3; 27 pp.(1977, February 15)

The reconnaissance sampling program for the Oak Ridge Gaseous Diffusion Plant (ORGDP) Uranium Resource Evaluation (URE) Project continued in the Texas Gulf Coast and Northwest

Texas. A pilot survey was also completed in the Upper Peninsula of Michigan. The "Reconnaissance Geochemical Survey in the Crystal City and Beeville Quadrangles, Texas" was prepared for submission to ERDA in January 1977. The survey represents the first reconnaissance report and includes the technical evidence that the ORGDP concept of Phase I and Phase II sampling with multielement analysis is valid. A project status and summary of URE activities during the quarter are presented in this report. Also included is a listing of plans for the Second Quarter FY 1977. (Auth)

159
Arendt, J.W.; Union Carbide, Oak Ridge Gaseous Diffusion Plant, Oak Ridge, TN

Hydrogeochemical and Stream Sediment Reconnaissance Program in Central United States, FY 1976 - July 1, 1976 - September 30, 1976. K/UR-3, Part 1; 59 pp.(1976, November)

The production sampling program for the Uranium Resource Evaluation (URE) Project continued in the Texas Gulf Coast and was started in Northwest Texas. Pilot surveys were completed in North Dakota, South Dakota, Minnesota, and Wisconsin; and a pilot survey was started in the Upper Peninsula of Michigan. The Northwest Texas Pilot Survey was prepared for open filing by ERDA. Modification of the URE Clean Room Laboratory was completed. The laboratory layout is presented, and the analytical instrumentation is described. A project status and summary of UCC-ND activities during the quarter are presented in this report. Also included is a listing of plans for the First Quarter FY 1977. (Auth)

160
Arendt, J.W.; Union Carbide, Oak Ridge Gaseous Diffusion Plant, Oak Ridge, TN

Hydrogeochemical and Stream Sediment Survey in Central United States, Fourth Quarter FY 1975, April 1, 1975 - June 30, 1975. GJBX-29(76); K-TL-524, Part 1; 15 pp.(1975, September 2)

The National Uranium Resource Evaluation (NURE) Program will be administered by the Grand Junction Office (GJO) of the U.S. Energy Research and Development Administration (ERDA). One part of this program consists of a hydrogeochemical and stream sediment survey of the entire United States (U.S.). Union Carbide Corporation, Nuclear Division (UCC-ND) will conduct this survey over approximately one million square miles of the Central U.S., which includes the states of Illinois, Indiana, Iowa, Kansas, Michigan, Minnesota, Nebraska, North Dakota, Oklahoma, Texas, South Dakota, and Wisconsin. Lawrence Livermore Laboratory (LLL), Los Alamos Scientific Laboratory (LASL), and Savannah River Laboratory (SRL) have accepted similar responsibilities for coverage of the remaining states. The objective of UCC-ND is to carry out an innovative and cost effective hydrogeochemical and stream sediment survey program, in order to provide high quality, meaningful data which can be used to identify areas favorable for detailed uranium prospecting. Information from other Government agencies and private industry is being obtained for incorporation into the program planning. In accomplishing this objective, coordination with LLL, LASL, and SRL will ensure a minimum of duplication in planning and development activities. A new organization called the Uranium Resource Evaluation Project has been formed within the Oak Ridge Gaseous Diffusion Plant (ORGDP) operated by UCC-ND. The full support facilities and technical personnel within the gaseous diffusion plants in Oak Ridge and Paducah, the Holifield National Laboratory (HNL), and the Y-12 Plant, also operated by UCC-ND, will be utilized by this project. A Project Manager, with a team of 10 to 12 people, will coordinate activities in analytical chemistry, geology and geochemistry, planning and statistics, field sampling, data management and information systems, and quality control. Work has already begun in analytical chemistry and planning. A quarterly progress report is intended to provide an update of all activities in progress. Auth)

161
Arendt, J.W.; Union Carbide, Oak Ridge Gaseous Diffusion Plant, Oak Ridge, TN

Hydrogeochemical and Stream Sediment Survey in Central United States, Second Quarter FY 1976, October 1, 1975 - December 31, 1975. K-TL-524, Part 3; 67 pp.(1976, February 27)

The production sampling program for the Uranium Resource Evaluation (URE) Project is scheduled to begin during the third week of January 1976. Project decisions on sampling and

analytical methodology were developed this quarter in order to meet the scheduled start date. Data management and quality control proposals were submitted to ERDA for the URE Project. The data management proposal was to develop and implement a broad base system for information retrieval and processing to serve the needs of the URE Project and to provide the capability for ERDA to interface with their centralized NURE information system. The quality control proposal was for a multilaboratory and sampling error control program. A project status and summary of UCC-ND activities during the quarter is presented in this report. Also included is a listing of plans for the third quarter FY 1976. (Auth)

162
Arendt, J.W.; Union Carbide, Oak Ridge Gaseous Diffusion Plant, Oak Ridge, TN

Hydrogeochemical and Stream Sediment Survey in Central United States, First Quarter FY 1976, July 1, 1975 - September 31, 1975. GJBX-30(76); K-TL-524, Part 2; 47 pp.(1975, November 26)

Work continued during the quarter to determine the analytical and sampling methodology to be used by UCC-ND in the Hydrogeochemical and Stream Sediment Survey. A sampling training session at Denver, Colorado was coordinated with the U.S. Geological Survey (USGS) for all participants in this project. Also, a sampling trip was made to Texas in cooperation with Savannah River Laboratory (SRL) personnel. Several industry contacts were made to obtain their ideas, particularly those regarding desired data which could be incorporated into the NURE Program. UCC-ND is continuing to receive excellent cooperation from the other Federal agencies, in particular USGS and the Environmental Protection Agency (EPA). This is very important toward minimizing duplication of effort. Work continued on the development of a quality control (QC) plan which will provide the proper quality level and ensure that the final report will be reliably useful to industry. Procedures are being developed for preparing solution batches and for screening and blending sediment batches. A summary of UCC-ND activities during the quarter is presented in this report. Also included is a listing of plans for the second quarter. Future quarterly reports will show a comparison of accomplishments versus projected plans. (Auth)

163
Arendt, J.W.; Union Carbide, Oak Ridge Gaseous Diffusion Plant, Oak Ridge, TN

Hydrogeochemical and Stream Sediment Survey in Central United States, Third Quarter FY 1976, January 1, 1976-March 31, 1976. K-TL-524, Part 4; 59 pp.(1976, May 10)

The production sampling program for the Uranium Resource Evaluation (URE) Project began in Texas during January 1976. Detailed sampling plans were completed for FY 1976 and FY 1976A. Preliminary plans were completed for the remainder of the program. The sampling plan was adjusted to ERDA regional priorities identified at the third quarter FY 1976 meeting held in Grand Junction, Colorado on January 21 and 22, 1976. Production and quality control samples are being analyzed in the URE Clean Room Laboratory and the results recorded in the URE data base. Detailed plans were completed for receiving, handling, and storage of URE samples. A project status and summary of UCC-ND activities during the quarter is presented in this report. Also included is a listing of plans for the fourth quarter of FY 1976. (Auth)

164
Armands, G., and S. Landergren; Aktiebolaget Atomenergi, Stockholm, Sweden

Geochemical Prospecting for Uranium in Northern Sweden - The Enrichment of Uranium in Peat. International Geological Congress, Proceedings of a Conference, Copenhagen, Denmark, 1960. Part 15, Genetic Problems of Uranium and Thorium Deposits, (pp. 51-66), 164 pp.(1960)

Several samples from a highly uraniferous peat indicated that the comparatively high content of uranium and radon was connected with the occurrence of radioactive springs within the region. Four different kinds of waters were responsible for the supply of radioactive material to the peat: surface water, ground water, spring water, and ground water emanating from fractured rock. The spring water-probably a mixture of ground water and water from the fractured rock-contained uranium of the magnitude 100 micrograms per litre. The pH was about 7. The content of uranium from the water system deriving from the fractured rock was about

200-300 micrograms per liter. The content of radon was about 15,000 countings per minute. The enrichment of uranium seems to be due to a long distance transport of Mg- and Ca-bicarbonates emanating from dolomite deposits in the vicinity of the peat, whereby the bicarbonate waters served as carriers of uranium. (Auth)(PAG)

165
Balasanov, G.N., D.Ya. Surazhskii, B.A. Chumachenko, A.A. Deryagin, and E.P. Vlasov

The Application of Mathematical Methods in Prospecting for Uranium Deposits. Soviet Journal of Atomic Energy 25(1):1064-1070.(1968, July)

An approach to the problem of directed-search for ore deposits is discussed in this article. The approach reduces it into two separate problems: 1) the division of the available sample of test points into classes corresponding to blocks oriented in specific directions with respect to the ore body. It is shown that this is a problem of recognition without incentive. A self-teaching algorithm was developed for the formation of classes in one of the possible variants of the problem; 2) the orientation of the neighborhood of and in the interior of the ore body of observation points, described by the vector of the geological, geochemical, and geophysical parameters under consideration. This is a problem of recognition with incentive. A possible method of solution is proposed for the most general case in which the types and parameters of the distribution function of representations into classes are unknown. The solution variant reduces to the construction of self-limiting process for the search for a solution-structure optimum with respect to the learning sample. A method is described for predicting the metal content per unit intersection; this method is based on a known uranium-molybdenum ore formation. An estimate is obtained of the relative effectiveness of linear and non-linear multiple regression in the construction of stochastic models of the relation between geological and geochemical points of observation and their position in the surrounding space and in the interior of an ore body. (JMT)

166
Barrett, L.P.; Jones and Laughlin Steel Corporation, Ishpeming, MI

A Sampling and Radiation Analysis of the Precambrian Rocks of Michigan, Minnesota, and Wisconsin. RME-3032; 16 pp.(1953, February)

A scintillometer survey and radiologic sampling of Pre-Cambrian formations in Michigan, Minnesota and Wisconsin found important radioactivity only in the Upper Huronian formations. The Goodrich conglomerate at the base locally carries thorium in excess of 0.1. The black graphitic slates carry about 0.003 U3O8 equivalent as an average. Concentrations of 0.1 or more U3O8 occur in veins cutting black slate and in certain zones in oxidized phases of the iron formation. The suggestion is made that post-oxidation hydrothermal solutions dissolved uranium from the black slate and redeposited it in the veins and in favorable zones in the iron formation. Only a small proportion of favorable host rock is available for radiation testing or sampling but current exploration for iron ore in the Upper Huronian high phos iron formation is in itself exploration for uranium. It is possible that future exploration or iron mine development may result in discovery of commercial uranium deposits. (Auth)

167
Baucom, E.I., V. Price, and R.B. Ferguson; Savannah River Laboratory, Analytical Chemistry Division, Aiken, SC

SRL Hydrogeochemical and Stream Sediment Reconnaissance - Preliminary Raw Data Release - Winston-Salem 1 Degree by 2 Degree NTMS Area, North Carolina, Virginia, Tennessee. GJBX-66(77); DPST-77-146-1; 123 pp.(1977, September)

Stream sediment samples were collected from small streams at 1399 sites in the Winston-Salem quadrangle. Samples were analyzed for uranium and 15 other elements by neutron activation analysis. Data included are: (1) water quality measurements (pH, conductivity, and alkalinity), (2) elements related directly to potential uranium and thorium mineralization in crystalline rock (U, Th, Hf, Ce, and Dy), (3) elements useful for geologic classification of the sample area (T, V, Fe, Mn, Al, and Sc), (4) sample site descriptors (stream characteristics, vegetation, etc.), and (5) supplementary elements that may be useful (Eu, Tb, Ta, Cs, and F). Uranium concentration ranged from 0.8 to 62.1 ppm and averaged 5.3 ppm. It is

suggested that most of the uranium in stream sediment samples is present in resistate minerals. (PAG)

Appendix A contains a description of the study area, Appendix B contains the reconnaissance data, and Appendix C contains a brief discussion of elemental distributions.

168
Baumgardner, L.; AEC, Grand Junction Office, Grand Junction, CO

Preliminary Reconnaissance of the Central Zuni Uplift, New Mexico. TM-98; 21 pp.(1956, November 26)

Two new localities of anomalous radioactivity were found in the central part of the Zuni uplift. Anomalous radioactivity was found in the San Andres limestone within the Bluewater fault zone, but no direct connection between the fault and the source of radioactive material was observed. No evidence of uranium was found in connection with other faults within the central Zuni area, and no confirmation was found for the hypothesis that uranium may have risen from deep sources within the central Zuni area and migrated thence along fault zones northeastward to the known deposits in the Todilto limestone and Morrison formation beyond the broad Grants valley. At the Copper Hill locality, uranium is associated with copper and carbonaceous material in a basal arkosic conglomerate of the Permian Abo formation resting on granite. No anomalous radioactivity was detected at the Section 21 fluorspar mine, nor in connection with the faults and basaltic lavas and tuffs of the belt of extrusives extending across the southeast end of the Zuni uplift. (Auth)

169
Berbezier, J., B. Blangy, J. Guitton, and C. Lallemant; Commissariat a l'Energie Atomique, France

Methods of Car-borne and Air-borne Prospecting: The Technique of Radiation Prospecting by Energy Discrimination. Peaceful Uses of Atomic Energy, Proceedings of the 2nd United Nations International Conference, Geneva, September 1-13, 1958. United Nations, Vol. 2, Survey of Raw Material Sources, (pp. 799-814), 843 pp.(1958)

The importance of methods of car-borne and air-borne prospecting and of discrimination applied to prospecting for uranium minerals evaluated. It is of interest that in car-borne prospecting the three types of detectors give satisfactory results; the interest of scintillometry resides in the rapidity of the execution of a program. Moreover, the use of plastic scintillators greatly reduces the cost of the apparatus. In systematic aerial prospecting, the experience acquired by the Commissariat a l'Energie Atomique (C.E.A.) in numerous expeditions confirms the necessity of increasing the sensitivity of detectors and thus of using plastic scintillometers of all kinds which are both nonfragile and economical. The difficulties encountered in the compilation of results emphasize the different parasitic effects which are responsible for false anomalies. The study of these parasitic effects leads to the identification of the nature of anomalies during flights. The discrimination scintillometer, by means of the total count channel, solves the problem of the lack of sensitivity of present scintillometers. By the additional channels with thresholds it offers the possibility of reducing the influence of parasitic effects and of isolating radioactivity from uranium-bearing sources. (MLB)

Tables and graphs are included in this report.

170
Bolivar, S.L., D.E. Broxton, and C.E. Olsen; Los Alamos Scientific Laboratory, Los Alamos, NM

Uranium Hydrogeochemical and Stream Sediment Reconnaissance of the Denver and Greeley NTMS Quadrangles, Colorado. GJBX-60(78); LA-7177-MS; 138 pp.(1978, March)

A total of 1264 water and 1060 sediment samples were collected from 1612 locations in the Denver quadrangle; 1210 water and 984 sediment samples were taken at 1520 locations in the Greeley quadrangle. Samples were collected at a nominal density of one per 10 square kilometers over a 38,000 square kilometer area. Water samples were collected from streams, springs, wells, natural ponds, and artificial ponds; sediment samples were collected from streams, springs, natural ponds, and artificial ponds. The major clusters of anomalous water samples were found in areas of the Denver Basin underlain by the Pierre, Laramie, Fox Hills, Denver, and Arapahoe

formations. Most of the anomalous sediment samples were collected in areas of the Front Range underlain by Precambrian crystalline rocks, particularly granites of the Silver Plume-Sherman group. Many of the anomalous sediment samples are from sites located near fault zones. Denver Basin waters had a higher mean uranium concentration (14.4 ppb) than Front Range waters (3.3 ppb). Front Range sediments are more uraniferous (mean 14.7 ppm) than those in the Denver Basin (mean 6.1 ppm). These differences in background uranium concentrations between Front Range and Denver Basin samples can be attributed to differences in regional geology, physiography, and (in the case of water) the ratio of surface water to ground water sites sampled. There is a significant northward increase in uranium concentrations in water samples from the Denver Basin. The higher uranium concentrations in water samples from the northern part of the basin are probably due to leaching of uraniferous strata in the Pierre and Laramie formations which crop out in that area. (PAG)

The following appendices are included in the report: Appendix A - Standard Field and Analytical Procedures; Appendix B - Field and Uranium Data for the Water Samples; Appendix C - Field and Uranium Data for the Sediment Samples; Appendix D - Code to Data Listings; Appendix E, F, and G - Frequency Distribution Histograms for Uranium Concentrations in Water and Sediment Samples

171
Boyle, T.L.; AEC, Grand Junction Office, Grand Junction, CO

Low-Level Aerial Radiometric Surveying in the USA. Peaceful Uses of Atomic Energy, Proceedings of the 2nd International Conference, Geneva, August 8-20, 1955. United Nations, Vol. 6, Geology of Uranium and Thorium, (pp. 820-824), 825 pp.(1958)

Aerial radiometric exploration has evolved into an effective and accepted uranium exploration tool with various modifications of equipment and methods available for special purposes or field conditions. It is not, however, the most useful or economical exploration approach possible under all circumstances. Initial and operating costs for low-level aerial prospecting compare favorably with costs for most other exploration techniques. Initial equipment costs for an airborne unit are approximately $11,000 and monthly operational costs average slightly more than $2000. The number of linear miles flown by Commission aircraft approximated 500,000 and the cost was about $1 per flight mile. Although aerial-survey initial and operating costs are acceptable, other considerations may preclude its use. In areas of heavy overburden or vegetation, aerial exploration is hampered or rendered ineffective. In addition, support facilities such as airports, refueling areas, and repair shops may be lacking in remote areas. Rugged topography, elevations in excess of 12,000 feet and bad climate may present difficult or insurmountable operating problems. In programming an airborne radiometric survey, the geologic characteristics of the area and the probable nature of the exploration target must be evaluated. If the geology of the area is favorable and excessive overburden or difficult terrain and climatic conditions are lacking, an airborne approach may be indicated. If other techniques are not available or if they appear to offer little or no advantage, the use of aerial low-level surveys becomes increasingly appropriate. Then, the cost of the proposed operation, commensurate with allocated funds, and the adequacy of materials, airports, and skilled personnel determine the employment of this exploration method. If, after considering the technical, scientific, and organizational aspects of the project, airborne radiometric surveying is undertaken, there is a good chance that an accurate evaluation of the uranium potential of a region will be obtained. (MLB)

Tables and figures are included in this paper.

172
Boyle, T.L.; AEC, Grand Junction Office, Grand Junction, CO

Airborne Radiometric Surveying - Office and Field Techniques. RME-129(rev.); 28 pp.(1963, July)

In the U.S. Atomic Energy Commission's method of airborne radiometric surveying commercially available scintillation counters are installed in light aircraft that are flown about 80 miles per hour at elevations of 25 to 100 feet. Ground crews examine all the anomalies detected and evaluate the discoveries. In the AEC program 81,000 square miles were aerially surveyed in 14 western states, and 1140 anomalies were located. The AEC's program began as an attempt to locate individual radioactivity anomalies and stimulate private uranium prospecting, but gradually changed to one of area evaluation and isoradiation mapping, the latter made possible by adding a recorder to

provide a permanent record of radiation intensity. The period of airborne exploration covered by this report demonstrated the use of aircraft as a tool for geologic reconnaissance and a means of readily detecting surface radioactivity. This type of exploration is especially suitable for remote, rugged areas. (Auth)(MLB)

173
Brooke, G.L., R.F. Shirley, and M.A. Swanson; AEC, Division of Raw Materials, Exploration Branch, Grand Junction, CO

Geological Investigations Report of the North Wash Mining District, Henry Mountains, Utah. RMO-704-R; 10 pp.(1951, October 18)

Mining in the North Wash mining district of the Henry Mountains is limited almost entirely to small surface pits. Approximately 1,150 tons of ore assaying 0.40 percent U3O8 and 2.0 percent V2O5 have been mined and shipped from the area since November 1950. The ore is found in the Salt Wash Member of the Morrison Formation, and the mineralization is of the carnotite-vanoxite variety. The area warrants some exploration and a program of 12,600 feet of wagon drilling is recommended. (Auth)

174
Brooks, R.R; Massey University, Department of Chemistry and Biochemistry, Palmerston North, New Zealand

Bryophytes as a Guide to Mineralization. New Zealand Journal of Botany 9:674-677.(1971)

The use of bryophytes in mineral exploration is reviewed. Copper mosses" grow preferentially over substrates with high copper concentrations. In New Zealand, aquatic bryophytes were used in the search for uranium since they concentrate this element from streams draining uraniferous areas. Samples were collected, washed, ashed at 450 degrees C, and analyzed for uranium by a fluorimetric method. Values as high as 100 ppm were encountered in streams draining uraniferous areas. (PAG)

175
Brown, L.J., and W. Easton; AEC, Division of Raw Materials, Denver Exploration Branch, Denver, CO

Results of an Airborne Reconnaissance for Uranium in Southeastern and South Central Colorado. RME-1059; 14 pp.(1955, April 7)

An airborne reconnaissance of the Huerfano Embayment, Las Animas Arch, and the La Veta Pass Area was conducted solely with rim flying procedures. Flight elevations varied between 50 and 100 feet, depending on the terrain and flying conditions. Six anomalies were located; three were located in the Huerfano embayment. These three anomalies were in a Tertiary granitic intrusive that registered almost twice background. A fourth anomaly, located in alluvium above the Pierre shale in the Las Animas Arch, showed abnormal radioactivity 16 times greater than background. The fifth anomaly was located in the Tertiary Ogallala formation near Calhan, Colorado. This anomaly, in a shaly member surrounded by clays, showed abnormal radioactivity 2 1/2 times background. The sixth anomaly in the Pierre shale near Wetmore had a maximum count of almost three times background. (PAG)

176
Brown, L.J., and R.C. Malan; AEC, Division of Raw Materials, Denver Exploration Branch, Denver, CO

Reconnaissance for Uranium in the South Central Part of Colorado. RME-1044; 17 pp.(1954, June 1)

The Sangre de Cristo Mountains, the San Luis Valley adjoining them on the west, the belt of upturned sediments adjoining them on the east, and part of the Canon City embayment were examined for uranium. Traverses were made with carborne and hand carried scintillation counters. Several pegmatite dikes in the Precambrian metamorphic complex on the western slope of the Sangre de Cristo Mountains show local abnormal radioactivity. In the La Veta Pass area, the mineralized zone extends for about 25 miles in undifferentiated Permian-Pennsylvanian red sandstone. The mineralized outcrops are characterized by carnotite and secondary minerals of vanadium and copper. Flay-lying Cretaceous and Jurassic sediments were examined in the Canon City embayment area with only the Dakota sandstone showing anomalous radioactivity. (Auth)(PAG)

177
Broxton, D.E., and N.P. Nunes; Los Alamos Scientific Laboratory, Los Alamos, NM

Uranium Hydrogeochemical and Stream Sediment Reconnaissance Data Release for the Wyoming Portions of the Driggs, Preston, and Ogden NTMS Quadrangles. GJBX-70(79); LA-7181-MS; 91 pp.(1978, April)

A total of 1108 water samples and 1956 sediment samples were taken from 1999 locations within the Wyoming portions of Driggs, Preston, and Ogden quadrangles. An additional 108 water samples and 128 sediment samples from 129 locations were collected in the Grand Teton National Park. The mean uranium concentrations for water samples are: Driggs, 0.80 ppb; Preston, 1.23 ppb; and Ogden, 6.64 ppb. The mean uranium concentrations for sediment samples are: Driggs, 7.07 ppm; Preston, 3.06 ppm; and Ogden 3.44 ppm. (PAG)

The following appendices are included in the report: Appendix A - Standard Field and Analytical Procedures; Appendix B - Field and Analytical Data for Water Samples; Appendix C - Field and Analytical Data for Sediment Samples; Appendix D - Keys to Codes Used in Data Listings.

178
Cady, J.W.; USGS, Denver, CO

Regional Gravity and Aeromagnetic Studies Applied to Uranium Exploration in Northeastern Washington and Wyoming. USGS Open-File Report 76-317; 21 pp.(1976)

Regional gravity and aeromagnetic maps are used in an attempt to elucidate regional geology in the vicinity of the Midnite Mine in Washington and the uranium districts surrounding the Sweetwater uplift in Wyoming. Most of the data were obtained from public-access sources. Correlations between the data and anomalies are discussed and possible places for uranium exploration pointed out. (MLB)

Maps are included in this report.

179
Campbell, R.H.; USGS, Washington, DC

Reconnaissance for Radioactivity in the Gold Hill Mining Area, Boulder County, Colorado, Part 1. TEM-563A; 27 pp.(1955, February)

Nearly all the veins examined, regardless of zonal position, are noticeably more radioactive than the adjacent country rocks. If these veins constitute a representative sample, radioactivity slightly higher than that commonly found in the country rocks is typical of the veins of the area. This suggests that some radioactive material was probably introduced with nearly all the vein-filling material. The known uranium deposits in the Gold Hill area are small and fairly widely scattered and are probably not of immediate economic importance. Most of the deposits, having a grade of 0.10 percent eU or more, are estimated to contain less than one ton of uranium ore. All of the deposits where uranium minerals have been observed are within the northwestern favorable zone. In nine radioactive deposits where uranium minerals were not observed samples show 0.10 percent eU or more; six of these are in the northwestern favorable zone. Thus, although radioactive deposits are not restricted to this favorable zone, it is possible that the concept of a preferred zonal position for uranium is applicable to the Gold Hill mining area. As ore minerals were observed in only a few of the veins examined, little can be concluded as to whether the uranium deposits are genetically associated with the telluride ores or the sulfide ores. (MLB)

180
Caneer, W.T., and N.M. Saum; Colorado School of Mines, Research Institute, Golden, CO

Radon Emanometry in Uranium Exploration. Mining Engineering 26(5):26-29.(1974, May)

The radon emanometry method in uranium exploration is described. The presence of radon 222 is specific for uranium whereas gross radiation is not. The gamma radiation may result from thorium. Thorium also has radon daughter (radon 220-thoron). However, the half-life for the radon whose ultimate parent is uranium is approximately 3.8 days. The half-life of the radon whose ultimate parent is thorium is measured in seconds. The nature of the alpha detecting equipment allows for discrimination between the two types of radon. The method uses the dispersion capacity of radon gas from the place of its origin to the surface above the underground uranium deposit. Soil gas is drawn using probes from boreholes 5 to 10 cm in diameter from a depth of around one meter. The effects of geological and geochemical factors (rock type, permeability, faulting and fracturing, humidity, etc.) on the radon content in surface layers are discussed. (MLB)

181
Cannon, H.L., and W.H. Starrett; USGS, Washington, DC

Botanical Prospecting for Uranium on La Ventana Mesa, Sandoval County, New Mexico. USGS Bulletin 1009-M, (pp. 391-407).(1956)

A uranium-bearing coal of the Allison and Gibson members (undifferentiated) of the Mesaverde formation of Late Cretaceous age crops out in erosional remnants of La Ventana Mesa. Analyses of the coal show the uranium to be concentrated locally, along with minor accumulations of sulfur, selenium, chromium, copper, lead, cobalt, molybdenum, and nickel. It is believed that the metals have entered the coal along fractures in the overlying La Ventana sandstone member and that the source of the metals may have been Pliocene Bandelier tuff. Plant distribution studies indicate that selenium- and sulfur-indicator plants, including species of ASTRAGALUS, STANLEYA, several Crucifers, and ERIOGONUM, which grow on the slopes below the coal outcrop, may be useful in prospecting along the base of other mesas in the area. On the buttes of La Ventana Mesa the coal is capped by a well-fractured 65-foot sandstone bed through which roots of a pinyon and juniper forest penetrate. More than 200 samples of branches of trees growing on top of the mesa were collected and analyzed for uranium. The assays ranged from 0.1 to 2.3 ppm of uranium in the wood ash. Dead branches, which were found to contain more uranium in the ash than live branches, were sampled whenever possible. The resulting uranium values have been contoured to indicate probable areas of mineralized coal. Parts of the north butte are recommended as favorable for physical exploration. (Auth)

182
Chenoweth, W.L.; AEC, Grand Junction Office, Grand Junction, CO

A Reconnaissance for Uranium in the Uppermost Cretaceous and Early Tertiary Rocks of the Eastern San Juan Basin, New Mexico. RME-97, (Part 2); 19 pp.(1957, May)

A reconnaissance of the uppermost Cretaceous and early Tertiary rocks of the eastern San Juan Basin failed to locate any uranium occurrences with immediate commercial possibilities. Three lithologic units were recognized during the study which appear favorable for uranium deposits. These are the Yegua Canyon facies of the San Jose Formation, the heavy sandstone facies of the Nacimiento Formation and the Ojo Alamo Sandstone. The Yegua Canyon facies contains widely distributed occurrences of uranium and is judged to be the most favorable host rock in the area. However, because of the large amount of dissection to this resistant facies by the present day erosion cycle, the potential is regarded as low. The potential of the heavy sandstone facies Nacimiento Formation is unknown because of the lack of surface anomalies and the limited area of outcrops, but is probably low. Although minor occurrences are present, the potential of Ojo Alamo Sandstone is regarded as very low due to the overall thinness of the formation. Observations at the known occurrences have indicated that limonite staining of sandstone is the best guide to radioactivity in the San Jose Formation and the Ojo Alamo Sandstone. Other parts of the San Juan Basin containing the Yegua Canyon facies of the San Jose Formation and the heavy sandstone facies of the Nacimiento Formation should not be overlooked for additional small deposits. (MLB)

183
Cowart, J.B., and J.K. Osmond; Florida State University, Department of Geology, Tallahassee, FL

Uranium Isotopes in Groundwater: Their Use in Prospecting for Sandstone-Type Uranium Deposits. Journal of Geochemical Exploration 8:365-379.(1977)

The uranium isotopic patterns in aquifers associated with uranium deposits in the Powder River and Shirley Basins of Wyoming, and in Karnes County, Texas were investigated. In addition, the Carrizo sandstone aquifer of Texas was studied in detail and the presence of a uranium accumulation was inferred. Sandstone-type uranium deposits accumulate at a reducing barrier with the groundwater circulation system. When regional uplift brings such uranium deposits into a more oxidizing environment, the circulating groundwater dissolves and disperses the ore, causing a concentration halo. This model is the basis for standard hydrogeochemical exploration for uranium. Where conditions have remained more stable, however, the accumulation process continues and no concentration halo is produced. In this case, the presence of mineralization is indicated by a decrease in uranium concentration in the downdip water, and

more specifically, by a significant increase in the U 234/U 238 activity ratio. This isotopic signal, generated by uranium deposits in sandstones, is discernible for a number of kilometers in the direction of flow, and comparison of these data with water samples in the area of recharge may prove to be a useful indicator for the location of such deposits. (JMT)

184
Daniels, J.J., J.H. Scott, P.D. Blackmon, and H.S. Starkey; USGS, Denver, CO

Borehole Geophysical Investigations in the South Texas Uranium District. Journal of Research of the USGS 5(3):343-357.(1977, May)

Contrasts of electrical properties between uranium deposits and their host rocks in South Texas are subtle. In places where deposits are small or deep, conventional geophysical well-loging techniques and hole-to-hole measurements may be the only practical method to detect changes in rock properties associated with the occurrence of uranium ore deposits. Two separate ore-producing areas in South Texas were chosen for studying borehole geophysical techniques applied to uranium-exploration problems. Extensive measurements of physical properties were made on cores and taken from holes where electrical-resistivity, induced-polarization and gamma-ray logs were run. These analyses show that: (1) induced-polarization anomalies are caused by a change in pyrite content and clay-sized material content and (2) resistivity anomalies are associated with a change in clay-sized material content and cementation. In addition to conventional borehole techniques, hole-to-hole induced-polarization and resistivity tests were made in South Texas. These measurements were made by placing a current source down one hole and a receiver cable down an adjacent hole whose separation ranged from 30 to 300 m and hole depths varied from 80 to 270 m. These tests show that hole-to-hole measurements can be used to detect changes in physical properties, associated with uranium ore, that occur between boreholes. Hole-to-hole measurements provide a link between surface measurements and well logs and can minimize the amount of drilling needed to locate an ore deposit. Accordingly, borehole geophysics will become an increasingly important evaluation tool as mineral exploration goes deeper. (Auth)

Locations of the properties investigated are proprietary information, and as such, not given in this paper.

185
Darnley, A.G., and M. Fleet; Canada Geological Survey, Ottawa, Ontario, Canada

Evaluation of Airborne Gamma-Ray Spectrometry in the Bancroft and Elliot Lake Areas of Ontario, Canada. Remote Sensing of Environment, Proceedings of the Fifth Symposium, Ann Arbor, Michigan, April 16-18, 1968. Willow Run Laboratories, Ann Arbor, Michigan, (pp. 833-854), 946 pp.(1968, September)

Airborne gamma-ray spectrometry provides a means of measuring the gross geochemical distribution of potassium-40, bismuth-214 and thallium-208 on the surface of the ground. It is the only remote sensing method so far developed which measures a property closely related to the chemical abundance of specific elements of scientific and economic interest, namely potassium, uranium and thorium. As such it makes a measurement which is of direct relevance to both conventional geological mapping and radioactive mineral exploration. The experiments were designed to establish the parameters for a sensitive gamma-ray spectrometer system suitable for operation from a fixed wing aircraft and at the same time to investigate various factors which complicate interpretation of radiometric measurements from a complex surface such as the Canadian Shield. These factors were deemed to include the effect of: variable amounts of rock outcrop; rugged topography; overburden of unknown origin; irregular distribution of swamp and water and forest cover. Investigation of these factors is not complete but sufficient information has been obtained to show they are not as detrimental to useful results as might be supposed. The ground results are presented as radiometric contours, with intervals drawn at multiples of the area modes for potassium-40, bismuth-214 and thallium-208. Ground and airborne results are compared in profile form, and close agreement is demonstrated. Intensity of radiation from outcrop and from overburden over the same rock type has been found to be similar. The fact that total radiation intensity is dominated by the contribution from over-burden does not appear to be unduly deleterious to the application of airborne gamma-ray spectrometry to geological

mapping. There is evidence to suggest that radiometric "signatures" can be derived from measurements over an area and that they will be useful for identifying rock units from the air. (Auth)(PAG)

186
Davis, H.C.; AEC, Raw Materials Division, Salt Lake City, UT

Summary Report of Reconnaissance and Exploration for Uranium Deposits in Northern Nevada. RME-2013; 28 pp.(1954, July)

Eight known areas of significant uranium occurrences were reported prior to the initiation of the reconnaissance. Ten new occurrences were reported and investigated. Only one of the occurrences has yielded commercial production. Pitchblende is known at four localities-Long Lease mine, East Walker River area, Stalin's Present prospect, and Cottonwood Canyon area. Meta-torbernite and torbenite are the most common secondary minerals occurring at East Walker River, Majuba Hills, Early Day and Truckee Canyon area. Other uranium minerals identified were carnotite, tyuyamunite, autunite, gummite, uranophane, kasolite, and phosphuranylite. One deposit contains thorium in the form of monazite and another deposit, rare earths (allanite). The western half of the state appears more favorable for uranium mineralization than the eastern part. (Auth)(MLB)

187
Dickson, R.E., R.G. Blair, H.R. Hart, J.V.A. Sharp, and C.D. Thompson; AEC, Grand Junction Operations Office, Grand Junction, CO

Drilling Results and Favorability Criteria in Bull Canyon, Montrose and San Miguel Counties, Colorado. RME-42, Part 1; 67 pp.(1955, April)

Eight hundred forty-four holes were diamond drilled detailing 99,000 feet of the Salt Wash Sandstone Member of the Jurassic Morrison Formation in the Bull Canyon Area. Three types of drilling: investigative, explorative, and developmental, were used in the study of the 10 areas in Bull Canyon. An additional 2,783 feet of wagon drilling, involving 30 holes, was conducted in two areas. First Rim orebodies occur from 30 to 60 feet above the base of the Salt Wash; commercial deposits in the Third Rim are found in the interval from 250 to 280 feet above the base of the Salt Wash. (PAG)

188
Dings, M.G.; USGS, Washington, DC

Radiometric Reconnaissance Near Montezuma, Summit County, Colorado. TEI-296, Part 1; 12 pp.(1953, February)

An area of about 5 square miles centering around Montezuma, Colorado was examined for radioactive materials. The region contains abundant northeast-trending steeply dipping fissure veins that cut Precambrian hornblende gneiss and quartz monzonite of Tertiary age. The typical vein minerals are galena, sphalerite, pyrite, and chalcopyrite in a gangue of quartz and barite. Abnormal radioactivity occurs at two prospects on two different veins; the uranium content ranges from 0.001 to 0.007 percent. (Auth)

189
Dings, M.G., and M. Schafer; USGS, Washington, DC

Radiometric Reconnaissance in the Garfield and Taylor Park Quadrangles, Chaffee and Gunnison Counties, Colorado. TEI-255, Part 1; 25 pp.(1953, February)

The region contains a relatively large number of rock types, chiefly pre-Cambrian schists, gneisses, and granites; large and small isolated areas of sedimentary rocks of Paleozoic and Mesozoic ages; and a great succession of intrusive rocks of Tertiary age that range from andesite to granite and occur as stocks, chonoliths, sills, dikes, and one batholith. The prevailing structures are northwest-trending folds and faults. Anomalous radioactivity is uncommon, and the four localities at which it is known are widely separated in space. The uranium content of samples from these localities is low. Brannerite, the only uranium-bearing mineral positively identified in the region, occurs sparingly in a few pegmatites and in one quartz-beryl-pyrite vein. Elsewhere radioactivity is associated with (1) black shale seams to the Manitou dolomite, (2) a quartz-pyrite-molybdenite vein, and (3) a narrow border zone of oxidized material surrounding a small lead-zinc ore body in the Manitou dolomite along a strong fault zone. (Auth)(PAG)

The Taylor Park Quadrangle (15') was surveyed in 1967 and divided into four 7.5' quadrangles-Italian Creek, Pieplant, Matchless Mountain, and Taylor Park Reservoir.

190
Dodd, P.H.; ERDA, Grand Junction Office, Grand Junction, CO

Uranium Exploration Technology. Geology, Mining and Extractive Processing of Uranium, Jones, M.J. (Ed.), Proceedings of a Symposium, London, January 17-19, 1977. Institute of Mining and Metallurgy, London, (pp. 158-171), 171 pp.(1976)

Uranium exploration methods and technology have evolved from three decades of experience, stimulated intermittently by a historically fluctuating demand for uranium. Standard techniques of exploration, geological mapping, aerial or ground-based gross gamma radiometric surveys, and exploration drilling are reviewed in this paper. Other techniques occasionally utilized include geobotanical prospecting, geochemical surveys, radon detection, and non-radiometric geophysical methods. Recent developments of technology to support exploration emphasize nuclear geophysics, such as sensitive gamma-ray spectrometry, direct uranium logging by use of fission neutron techniques, more sophisticated radon and helium emanometry, and an increasing interest in indirect geophysical and geochemical measurements by use of neutron-neutron and magnetic susceptibility. Although each improved technique improves the technology, it is the possible combination of techniques that will optimize exploration. To be most effective the techniques should be integrated and exploration methods predicated on sound geological-geochemical principles of uranium ore genesis. (Auth)(PAG)

191
Duray, J.R.; Bendix Field Engineering Corporation, Grand Junction, CO

A Brief Review of the Basis for, and the Procedures Currently Utilized in, Gross Gamma-Ray Log Calibration. GJBX-61(76); 8 pp.(1976, October)

The purpose of this paper is to bring together the various assumptions that are stated in the literature or are tacitly understood and which form the basis for the well known relationship between the grade-thickness product and the total or gross gamma ray response of a borehole probe. As this relation pertains to calibration, certain conditions have been established by the Energy Research and Development Administration (ERDA) in order to assure uniformity among the various gross gamma ray probes. That these conditions and their implications are sometimes misunderstood is an understatement. An example illustrating the analysis of digital calibration data is presented in the hope that such misunderstanding may be cleared up and at the same time demonstrate the efficacy of a few common integration techniques. (Auth)

192
Dyck, W., I.R. Jonasson, and R.F. Liard; Canada Geological Survey, Ottawa, Ontario, Canada; Projex Limited, Toronto, Ontario, Canada

Uranium Prospecting with Rn 222 in Frozen Terrain. Journal of Geochemical Exploration 5:115-127.(1976)

It has been shown that Rn 222 contents of soil gas can increase under snow-covered or frozen soils. By utilizing these observations and results of field tests described in the report, it can be stated that U prospecting with Rn 222 in frozen terrain is practicable. Rn profiles in frozen and snow-covered soils over U mineralization in the Bancroft area outlined known radioactive zones more clearly than did scintillometer profiles. Tests in the proximity of a radioactive pegmatite dike showed that lake ice acts as a restrictive barrier to Rn movement from lake waters beneath. Water samples, collected and allowed to freeze in plastic bottles, retained dissolved Rn quite effectively thus permitting sample collection and storage under the most severe winter conditions. Rn sampling of through-ice lake waters is therefore a feasible prospecting tool. Samples of spring run-off (snow-melt) waters and slushy snow collected from within a known weakly radioactive zone were shown to contain less Rn than found in the same stream waters in the summer. No pronounced Rn degassing event of frozen soils was apparent early in the spring thaw in percolating run-off waters draining from the zone. The usefulness of spring thaw hydrogeochemistry using Rn is discussed. (Auth)(MLB)

193
Eakins, G.R.; Alaska State Department of Natural Resources, Division of Geological and Geophysical Surveys, College, AK

Investigation of Alaska's Uranium Potential, Part 1: Reconnaissance Program, West-Central Alaska and Copper River Basin. GJBX-28(77), Part 1; GJO-1639, Part 1; 58 pp.(1977, February)

To aid in determining the uranium potential of Alaska, 916 stream-sediment samples and 427 bedrock samples were analyzed for uranium, thorium, and potassium oxide, and 565 water samples were collected for uranium analyses. The means, thresholds, anomalies, and U:Th ratios were calculated for eight separate regions. The alkaline plutonic rocks in the west-central part of the state contain unusual amounts of uranium and thorium. Stream-sediment samples from this region contained up to 111 ppm uranium, 150 ppm thorium, and 7.3 percent potassium oxide. Bedrock samples contained as much as 258 ppm uranium, 290 ppm thorium, and 17.19 percent potassium oxide. The U content of stream sediments was often higher than that of the surrounding bedrock, indicating a concentration of U in the streams. Water samples were found to generally be very low in uranium, but several anomalies were determined. The highest uranium content in the water samples was 3.95 ppb, obtained from a stream in the Zane hills. From the Copper River basin-Chitina River valley area, the Healy area, and the Eagle-Charley River area, the maximum U content of stream sediments was 10 ppm, rocks 2.5 ppm, and water 3.5 ppb. A limited number of calculations showed that nepheline syenite contained the most U (mean 12.83 ppm) of the seven most common igneous rock types. Granite was second (10.38 ppm U). The highest concentrations of U were found in alkalic dikes in the Darby Mountains and Selawik Hills, and in a broad zone in the Selawik Lake complex. Background radiometric readings were commonly 200 to 400 cps; the maximum was 2,000 cps over a dike in the Selawik Hills. In contrast with the plutonic belt in the western part of the state, radiometric readings obtained in the Copper River basin-Chitina River valley area were very low. The maximum reading in a single point was 160 cps, and the usual values were under 60 cps. (Auth)(PAG)

Data contained in the appendices are: Appendix A-Stream-sediment-, rock-, and water-sample analyses with radiometric data; Appendix B-Histograms; Appendix C-Correlation matrix; Appendix D-Determination of thorium, uranium, and potassium oxide in stream sediments and rocks; and Appendix E-General geology of areas investigated.

194
El Shazly, E.M., W.M. Meshref, A.A. Ammar, M.A. El Ghawaby, I.A. El Kassas, and M.M. El Rakaiby; Atomic Energy Establishment, Cairo, Egypt

New Developments in the Techniques of Uranium Exploration in Egypt, Case Histories for Exploration Under Arid Conditions. IAEA-CN-36/48; Nuclear Power and Its Fuel Cycle, Proceedings of a Symposium, Salzburg, Austria, May 2-13, 1977. International Atomic Energy Agency, Vol. 2, The Nuclear Fuel Cycle, Vienna, (pp. 301-314), 694 pp.(1977)

The arid conditions in the territories of Egypt give special applicabilities for uranium exploration techniques, which make some of these techniques either particularly useful and some not so useful or even useless. Cases encountered during uranium exploration operations in Egypt characteristic for arid zone conditions, even beyond the borders of Egypt are outlined briefly in the paper. These include airborne radiometry, aerial photography, radon emanometry, spaceborne imagery, and thermal infrared imagery. (MLB)

195
Ferguson, R.B., V. Price, and E.I. Baucom; Savannah River Laboratory, Analytical Chemistry Division, Aiken, SC

Field Manual for Stream Sediment Reconnaissance. GJBX-30(77); DPST-76-358; 56 pp.(1976, July)

The manual directs and coordinates field operations, site selection, sample collection, and information codes for the Savannah River Laboratory contribution to the National Uranium Resource Evaluation Program. The manual provides public relations information for field sampling teams as well as technical direction. Stream sediment sampling at an average density of one site per five-square-miles was conducted utilizing procedures as outlined in this manual. The area of responsibility for Savannah River Laboratory includes: Maine, New Hampshire, Vermont, Delaware, New York, Massachusetts, Rhode Island, Connecticut, Pennsylvania, Ohio, New Jersey, Maryland, West Virginia, Kentucky, Virginia, Missouri, Arkansas, Tennessee, North Carolina, South Carolina, Louisiana, Alabama, Mississippi, Georgia, and Florida. (PAG)

196
Ferguson, R.B., V. Price, and E.I. Baucom; Savannah River Laboratory, Analytical Chemistry Division, Aiken, SC

Field Manual for Ground Water Reconnaissance. GJBX-26(77); DPST-76-416; 66 pp.(1977, January)

The manual directs and coordinates field operations, site selection, sample collection, and information codes for the Savannah River Laboratory contribution to the National Uranium Resource Evaluation Program. The manual provides public relations information for field sampling teams as well as technical direction in ground water reconnaissance. The area of responsibility for Savannah River Laboratory includes: Maine, New Hampshire, Vermont, Delaware, New York, Massachusetts, Rhode Island, Connecticut, Pennsylvania, Ohio, New Jersey, Maryland, West Virginia, Kentucky, Virginia, Missouri, Arkansas, Tennessee, North Carolina, South Carolina, Louisiana, Alabama, Mississippi, Georgia, and Florida. (PAG)

197
Fincher, F.R., and T.W. Konigsmark; AEC, Grand Junction Office, Exploration Division, Grand Junction, CO

Exploration Drilling in the Haystack Butte Area, McKinley County, New Mexico. RME-120; 35 pp.(1957, January)

A drilling program was conducted to explore the Jurassic Todilto limestone for uranium occurrences on the eastern, northeastern, northern, and northwestern sides of Haystack Butte. Uranium mineralization in the area is closely associated with folds, faults, and joints, all of which are genetically related to the Zuni uplift. Uranium usually occurs in association with fluorite, barite, pyrite, and abundant hematite. A new technique of dry, non-core rotary drilling was found satisfactory, but contamination of samples occurred due to caving of poorly consolidated and unconsolidated minerals overlying the limestone. (Auth)(PAG)

198
Flawn, P.T., and G.H. Anderson; Texas Bureau of Economic Geology, University of Texas, Austin, TX

Prospecting for Uranium in Texas. Texas Bureau of Economic Geology Circular 37; 21 pp.(1955, February)

A brief review of vein deposits and deposits in sedimentary rocks precedes a description of the twelve regions where radioactive minerals are known or have been reported. The Llano region, north-central Texas region, Panhandle and south Plains area, Trans-Pecos Texas area, High Plains, and Gulf Coastal Plain are areas considered favorable for prospecting. General prospecting information and information on land classification in Texas are summarized. (PAG)

The section on Texas Lands is by J. Earl Rudder, Commissioner of the General Land Office, Austin, TX.

199
Foote, R.S.; Texas Instruments Incorporated, Dallas, TX

Application of Airborne Gamma-Radiation Measurements to Pedologic Mapping. Remote Sensing of Environment, Proceedings of the Fifth Symposium, Ann Arbor, Michigan, April 16-18, 1968. Willow Run Laboratories, Ann Arbor, Michigan, (pp. 855-876), 946 pp.(1968, September)

An airborne system for rapidly gathering large volumes of gamma-radiation spectral data was used to examine the uranium:thorium:potassium distribution in surface soils of an 80 sq miles region in Atascosa-Karnes-Wilson Counties, Texas. Data was accumulated using six NaI(Tl) detectors. All results giving the magnitudes of the uranium thorium, and potassium 40 - created radiation were first corrected for the spectral count contribution of the radioactive elements carried onboard the aircraft and contained in the atmosphere. Data was subsequently corrected to a constant surface elevation of 400 ft. Correlations of the U:Th:K output data were made for surface soil types. The soils were classified into six basic types: 1) clay loam, 2) fine sandy clay loam, 3) clay, 4) sandy clay loam, 5) loamy fine sand, and 6) loam. Results showed a strong correlation between the average uranium and thorium values and soil types. The extremely anomalous uranium mining region showed no anomaly in thorium. Potassium 40 indicated very little modulation. Bi 214, indicator of uranium, showed a broad anomalous region. The ratio, U/Th, removed a large portion of this anomalous region by

accounting for soil correlations and indicated two main anomalous regions to exist. (PAG)

Numerous charts and graphs are included in the report.

200
Freden, S.C. (Ed.), E.P. (Ed.) Mercanti, and D.B. (Ed.) Friedman; NASA, Goddard Space Flight Center, Missions Utilization Office, Greenbelt, MD; NASA, Goddard Space Flight Center, Technical Information Division, Greenbelt, MD

Third Earth Resources Technology Satellite Symposium, Vol. 2, Summary of Results. NASA-SP-356; Proceedings of a Symposium, Washington, DC, December 10-14, 1973. National Aeronautics and Space Administration, Washington, DC; 179 pp.(1974, May)

Volume 2, Summary of Results, highlights and summarizes the significant results from the technical presentations of the December 10-14, 1973, symposium. Typical examples of applications of ERTS data for solving resources management problems at the national, state, and local levels are presented. ERTS utilizing disciplines summarized are: Agriculture, Forestry, and Range Resources; Water Resources; Land Use and Mapping; and Mineral Resources, Geological Structures and Landform Surveys. (PAG)

Cited as a reference in NURE contractor reports.

201
Gabelman, J.W.; Utah International, Inc., San Francisco, CA

Migration of Uranium and Thorium - Exploration Significance. Studies in Geology No. 3, The American Association of Petroleum Geologists, Tulsa, Oklahoma, 168 pp.(1977)

A review of the possible mobilization and fixation processes is presented in this book. The author advocates the following additions to exploration technology: (1) Removal of the prejudice against any form of hypogene origin; (2) Wider consideration of secretionary mechanisms related to tectonic, metamorphic, and igneous processes; (3) Wider consideration of the role of regional tectonics in creating the combination of lithologic, structural, physiographic, and hydrologic factors which localize uranium districts at specific places; (4) Less emphasis on host rock stratigraphy and lithology as the only required ingredients for ore formation; (5) Wider consideration of the role of geopressurization as a mineralizing agent; (6) More consideration of the sources of uranium in ground circulation or unidirectional transport systems and the adequacy of uranium to form significant deposits once given the opportunity for fixation; (7) Wider and more intensive search for evidence of uranium transfer by mantle degassing, and of the deposits so formed; (8) More focus on taphrogenic feeding of uranium through tensional and wrench fault systems of regional proportions; (9) More focus on the surficial reduction of deposit quality and size by supergene leaching, and correspondingly greater attention to weak widespread occurrences which may represent leached residual; and (10) A better balance of commercial exploratory effort between conventional deposits (sandstone impregnations in the U.S.) and unconventional low-grade/high-cost resources so that such resources will be available to absorb the deficiencies of conventional deposit discoveries. (JMT)

Fourteen chapters of this book have been abstracted for the NURE Bibliographic Data Base.

202
Gangloff, A.M., C.R. Collin, A. Grimbert, and H. Sanselme; Commissariat a l'Energie Atomique, France

Application of Geophysical and Geochemical Methods to the Search for Uranium. Peaceful Uses of Atomic Energy, Proceedings of the 2nd International Conference, Geneva, September 1-13, 1958. United Nations, Vol. 2, Survey of Raw Material Sources, (pp. 140-147), 843 pp.(1958)

Geophysical and geochemical methods may complement the conventional radiometric indications in this fashion: the former may reveal a geological or tectonic structure and the latter give a more accurate, and particularly more specific, image of the distribution of the uranium in the ground than would a radiometric may. In addition, the use of these methods affords means of limiting the extent of the other work (digging and boring). They fairly quickly give a sound idea regarding the interest to be attached to each one of them. All in all they lead to an economy of money, and particularly to a gain of time, which is very important, in particular when the mining equipment program for a deposit or group of

deposits is taken into consideration. The principle of these methods are presented in the paper, along with the conditions for their application. Various geophysical methods are reviewed, dwelling at greater length on the electrical methods which make use of direct current, in view of their vast field application and low cost. Generally speaking, the possibility of using geochemical methods is dependent on the following: the mobility of the element sought, which determines its dispersion; the sensitivity of the analytical methods which must afford sure and rapid means of detecting the geochemical abnormalities. However, the combined use of geophysical and geochemical methods leads to rapid results which are complete and accurate enough, at relatively low cost. (MLB)

203
Givens, W.W.; Mobil Oil Corporation, Dallas, TX

Method and Apparatus for Uranium Exploration Employing Radioactive Reconnaissance and Assay Logging. Patent 994,477; 28 pp.(1976)

There is described a new and improved uranium prospecting procedure in which two delayed fission neutron (DFN) logs are run in an exploration borehole. The first DFN log is run for reconnaissance purposes and may be carried out after, or in lieu of, a preliminary run gamma ray log. Thereafter a second DFN log is run for assay purposes in order to obtain a quantitative indication of uranium content. (MLB)

The report is actually Canadian Patent No. 994477, issued August 3, 1976, to Mobil Oil Corporation, USA

204
Givens, W.W., W.R. Mills, C.L. Dennis, and R.L. Caldwell; Mobil Research and Development Corporation, Dallas, TX

Uranium Assay Logging Using a Pulsed 14-Mev Neutron Source and Detection of Delayed Fission Neutrons. Geophysics 41(3):468-490.(1976, June)

An in-situ uranium assay logging system has been developed that measures directly and quantitatively the uranium concentration in the formation surrounding a drill hole. System operation is based on the DFN (delayed fission neutron) method which involves (1) bombarding a formation with short duration bursts of neutrons from a pulsed-neutron generator to induce fission in any uranium present; (2) separating delayed fission neutrons, from source and prompt fission neutrons, by waiting a few milliseconds after each neutron burst before activating the neutron counter system; (3) deactivating the neutron counter system before the beginning of the next neutron burst; and (4) repeating this bombard-wait-count cycle a sufficient number of times to accumulate a statistically acceptable number of delayed neutron counts. The DFN logging method has been used routinely in our field operations for several years, and it has successfully overcome one of the most perplexing problems encountered in uranium exploration and production-that of radioactive disequilibrium. The need for coring and chemical assaying is virtually eliminated. The information provided by chemical assay of cores is made available by DFN assays on site and in minutes after the data are accumulated. The disequilibrium ratio is available to the field geologist immediately by computing DFN assay ore grade to ore grade from a calibrated natural gamma-ray log. A DFN uranium assay logging system is capable of 8 ft/minute continuous semiquantitative logs and stationary quantitative assays. Calibration procedures and a method for correcting DFN assays for variable formation parameters, such as porosity and macroscopic absorption cross-section, have been developed. DFN logs, assays, and chemical assays of cores are in excellent agreement. (MLB)

Numerous figures are included in this report.

205
Grammakov, A.G., N.V. Kvashnevskaya, A.I. Nikonov, M.M. Sokolov, N.N. Sochevanov, S.A. Suppe, and G.P. Tafeyev

Some Theoretical and Methodical Problems of Radiometric Prospecting and Survey. Peaceful Uses of Atomic Energy, Proceedings of the 2nd International Conference, Geneva, September 1-13, 1958. United Nations, Vol. 2, Survey of Raw Material Sources, (pp. 732-743), 843 pp.(1958)

Radiometric methods may be conditionally divided into two groups. In the first group are the so-called "prospecting methods", which are qualitative methods used in obtaining data for calculation of radioactive ore reserves. To the second group belong methods which have found

wide application in prospecting radioactive ore deposits, primarily gamma and emanation methods. Radiometric anomalies cannot be interpreted without consideration of geological and geochemical factors. In the paper some theoretical problems of gamma logging and testing are discussed as well as problems relating to field radiometric methods and comprising, along with this theory, the main features of application of these methods in prospecting uranium ores. (MLB)

206
Gregg, C.C., and E.L. Moore; AEC, Grand Junction Office, Geologic Branch, Grand Junction, CO

Drilling on the Ruth and Brigham Claims, Holbrook Area, Navajo County, Arizona. TM-81; 11 pp.(1956, March 21)

Drilling on the Ruth and Brigham claims disclosed small uranium orebodies and mineralization in the middle Chinle formation of Triassic age. The ore is concentrated in accumulations of carbon in paleostream channels and is often found above a white bentonitic mudstone. The four orebodies disclosed are extremely thin (average 1 foot) and small (100 by 50 feet), and average 0.15 percent U3O8. (Auth)(PAG)

207
Griffiths, J.C., J.A. Cochran, D.W. Groff, and J.G. Kahn; Pennsylvania State University, State College, PA

Petrographical Investigations of the Salt Wash Sediments: Progress Report for June 1 to October 1, 1953. RME-3070; 94 pp.(1953, December)

The results of a detailed analysis of the lithology of three inch cores from wells 155 A, B and C Bull Canyon are described and compared, and the gradients of change from ore in well A through a distance of 50 feet to well B and a further 50 feet to well C discussed. Only a few minor changes occur in the sand from C through B to A. Most of the changes are inconsisten. well B varying very much more than would be e..pected. Color, texture, and structure are associated in those cores. Lithological variation in terms of regions is briefly described on the basis of field excursions to the Colorado Plateau. It is shown that variability is the striking characteristic. the sediments being most variable in the Lukachukai area, moderately variable in the La Sal area and most uniform in the Montazuma area. The ore prospects are apparently a function of this variability. Spectrographic analysis of some mudstones for vanadium content is briefly described and it seems clear that ore is not confined to the sandstones. X-ray spectrometer analysis and electron micrographs of mudstones failed to differentiate any mudstone types. Investigation of limonite spots has been continued and the results from wells 155 A and B are compared with those from well C. Variations in kind and frequency per unit area suggest that limonite spots (which apparently reflect changes in carbonate in the sandstones due to oxidation) may be a guide to ore. Finally the disposition of ore in the sandstones is described in terms of regions, local areas, hand specimens and microscopic examinations. The outstanding importance of textural variation on all scales is emphasized. The disposition of the ore in the sand is shown to favor penecontemporaneous formation of the ores during sedimentation. The consequences of this hypothesis are briefly discussed. (Auth)(PAG)

208
Grundy, W.D.; AEC, Grand Junction Office, Geologic Branch, Grand Junction, CO

Investigative Drilling in the Bee Area, White Canyon, San Juan County, Utah. TM-102; 10 pp.(1957, February 28)

Thirty-seven holes ranging in depth from 22 to 393 feet and totaling 4,723 feet were drilled in the Triassic Shinarump member of the Chinle formation in the Bee area, Utah, to evaluate the uranium potential of the area. In only one hole, drilled to 169 feet, was ore-grade uranium encountered. A broad and shallow paleostream challel fill was traced for a distance of 2,100 feet. Argillaceous material is sparse in the basal channel fill, making it unfavorable for the deposition of uranium. Other criteria of favorability such as poor sorting, carbon trash, and pyrite are present. At drilling depths of over 400 feet, the Bee channel may possibly be deeper and narrower, making it relatively more favorable for uranium ore deposits. (Auth)(PAG)

209
Grutt, E.W., Jr.; ERDA, Grand Junction Office, Grand Junction, CO

Uranium Exploration Methods Development. Mining Congress Journal 63(4):60-67.(1977, April)

New and improved technology is being developed to support exploration by industry and the on-going federal programs. These developments range from modest improvements on established and relatively simple methods, such as gross gamma counting with portable instruments, through advanced state-of-the-art techniques, such as high sensitivity gamma-ray spectrometry, to research and development of new sophisticated measurement systems, such as direct uranium logging using neutron interrogation. Total United States energy consumption is likely to grow through the year 2000 at an average annual rate of 2.5 to 3.0 percent. Predictions are that by the end of 1985 nuclear plants totaling 145,000 Mw will be in operation. (Auth)(MLB)

210
Hill, D.E.; Los Alamos Scientific Laboratory, Los Alamos, NM

Uranium Concentrations in Lake and Stream Waters and Sediments from Selected Sites in the Susitna River Basin, Alaska. LA-6730-MS; GJBX-31(77); 26 pp.(1977, May)

During the summer of 1976, 141 water and 211 sediment samples were taken from 147 locations in the Susitna River basin in Alaska by the Geophysical Institute of the University of Alaska for the Los Alamos Scientific Laboratory (LASL). These samples were taken to provide preliminary information on the uranium concentrations in waters and sediments from the Susitna River basin and to test the analytical methods proposed for the NURE Hydrogeochemical and Stream Sediment Reconnaissance for uranium in Alaska. The uranium determinations resulting from the fluorometric analysis of the water samples and the delayed-neutron counting of the sediment samples are contained in the Appendixes of this report. The low levels of uranium in the water samples, many of which were below the detectable limit of the LASL fluorometric technique, indicate that a more sensitive analytical method is needed for the analysis of Alaskan water samples from this area. An overlay showing numbered sample locations and overlays, graphically portraying the concentrations of uranium in the water and sediment samples, all at 1:250,000 scale, for use with existing USGS topographic sheets, are also provided as plates. (Auth)

211
Horton, R.C.; Bendix Field Engineering Corporation, Grand Junction Operations, Grand Junction, CO

NURE Engineering Report, Carson Sink, Nevada, Borehole. GJBX-49(77); 15 pp.(1977, July)

The borehole site is underlain by deltaic sediments deposited by the Carson River. A deep borehole was drilled to penetrate the deltaic sediments and older Tertiary sediments and volcanic rocks. The upper 3,269 ft of the borehole consists of clay, silt, and sand, of Quaternary age, grading into Pleistocene deposits of Lake Lahontan, and then into the upper part of the Pliocene-Truckee Formation. The interval from 3,269 ft to 3,893 ft consists of interbeds of limestone, shale, siltstone, and sandstone, and is also part of the Truckee Formation. A sequence of basalt or andesite flows and basaltic to rhyolitic tuffs was penetrated from 3,898 to 6,996 ft. The upper part of this sequence may be the Truckee Formation, and the lower part of the Desert Peak Formation. Rhyolitic tuff and rhyolite were penetrated from 6,996 to 8,496 ft. These rhyolitic rocks may be part of the Old Gregory Formation. An altered andesite was encountered at 8,496 ft. A six foot core recovered from 8,502 to 8,512 ft contained uranium ranging from 1 ppm in the sands to 22 ppm in the rhyolite. Two samples of the andesite in the core contained 1 ppm and 2 ppm U_3O_8 respectively. (PAG)

Lithologic, hydrocarbon, mud-temperature, and drilling-rate logs; Compensated Densilog; BHC Acoustilog; Differential Temperature Log; Proximity Log-Minilog; Spectralog, Dual Induction Focused Log; and Compensated Neutron Log are included.

212
Johnson, D.H.; USGS, Washington, DC

Reconnaissance of Radioactive Rocks of Massachusetts. TEI-69; 16 pp.(1951, December)

Near Worcester pegmatitic rocks are estimated to contain about 250 pounds of uranium and 8,500 pounds of thoria per foot of depth. A central belt was estimated to contain about 0.0003 percent equivalent uranium but less than 0.001 percent uranium in nearly all roadside materials. In general the rocks of Massachusetts are estimated to average about 0.001 to 0.002 percent equivalent

uranium. Several occurrences of slightly more radioactive rocks were found but none of these samples contained more than 0.001 percent uranium by chemical analyses. It is therefore believed that Massachusetts is not favorable as a source of significant uranium deposits. (MLB)

Maps are included with the report.

213
Jonasson, I.R., and C.F. Gleeson; Canadian Geological Survey, Ottawa, Ontario, Canada

On the Usefulness of Water Samples in Reconnaissance Surveys for Uranium in the Yukon Territory. Canadian Geological Survey Paper 76-1C, Report of Activities, Part C, (pp. 241-248).(1976)

Areas of potential interest can be outlined by water surveys using U, F, Zn and SO4(2-) in any combination. U itself is obviously the best indicator of U mineralization but the apparent close association between U and F strongly promotes the use of F as well. Measurements of pH and Fe are valuable for interpretative purposes; clues to the presence of oxidizing sulphides and knowledge of adsorption controls on dispersion processes for U would be the main benefits. Background levels for U in waters from all regions studied are generally in excess of 0.5 ppb, a convenient level for rapid routine analysis. Levels of F under normal conditions usually are greater than 50 ppb which puts them into the most useful range of a fluoride electrode. Anomalous levels for Zn are often in excess of 5 ppb over a background of 0.5-1.5 ppb depending on local geology. (PAG)

214
Jones, B.K., and R.B. Forbes; Alaska State Department of Natural Resources, Division of Geological and Geophysical Surveys, College, AK

Investigation of Alaska's Uranium Potential, Part 2: Uranium and Thorium in Granitic and Alkaline Rocks in Western Alaska. GJBX-28(77), Part 2; GJO-1639, Part 2; 66 pp.(1977, February)

One hundred eight rock samples were selected from traverses across five plutons in western Alaska and analysed for uranium, thorium, and potassium. Modes were determined using point-counting techniques. The highest uranium concentrations detected were 86 and 92 ppm from a mineralized dike intrusion zone in the Selawik Lake Complex. Correlation coefficients were calculated in an attempt to relate the mineralogy to uranium and thorium content. When the sample set is considered as a whole there is little significant correlation. However, the analysis of individual plutons yields strong correlations between mineralogy and radioactivity. The mineralogical variable that correlates with uranium or thorium varies from one pluton to the next. Based on these correlations, mineralogical guidelines are offered for the selection of uranium enriched variants in four of the five plutons. (Auth)

Data contained in the appendices are: Appendix 1-Mineralogical and chemical data; Appendix 2-Alkaline igneous rocks; Appendix 3-Examples of correlation coefficients; and Appendix 4-Analytical techniques.

215
Jones, P.L., and R.B. Ferguson; Savannah River Laboratory, Analytical Chemistry Division, Aiken, SC

SRL Hydrogeochemical and Stream Sediment Reconnaissance - Preliminary Basic Data Release - Greensboro 1 Degree by 2 Degree NTMS Area, North Carolina and Virginia. GJBX-74(78); DPST-78-146-4; 174 pp.(1978, May)

Stream sediment samples were collected from small streams at 1240 sites and ground water samples were collected at 774 sites in the Greensboro NTMS quadrangle. Uranium and 16 other elements in sediments and uranium and 9 other elements in ground water were analyzed by neutron activation analysis. Uranium concentrations ranged from 0.5 to 65.2 ppm in sediments and averaged 5.7 ppm. Uranium concentration in groundwater samples ranged from about 0.001 ppb to 729 ppb with an average value of 1.42 ppb. The highest uranium values are in the granitic and gneissic rocks of the Smith River Allochthon and Raleigh Belt. The lowest values are concentrated in the Carolina State Belt. It is suggested that most uranium in stream sediment samples is present in resistate minerals. Data from stream sites include water quality measurements (pH, conductivity, and alkalinity), elements that may be related to potential uranium and thorium mineralization in this area (U, Th, Hf, Ce, and Dy), elements useful for geologic classification of the sample area (Ti, V, Fe, Mn,

Al, and Sc), sample site descriptors (stream characteristics, vegetation, stream width, etc.), and additional elemental analyses that may be useful (F, Eu, Sm, La, Yb, and Lu). Data from ground water sites include water chemistry measurements (pH, conductivity, and alk linity), elemental analyses (U, Na, Cl, Mg, Al, Mn, Br, V, and F), site descriptors, information about the collection of the samples (well age, well depth, frequency of use of well, etc.), and analytical data for dysprosium. (PAG)

Appendix A contains a description of the study area, Appendix B contains the reconnaissance data, and Appendix C contains a brief discussion of elemental distributions.

216
Kastelic, W.R., and K.E. Scott; AEC, Grand Junction Office, Grand Junction, CO

Reconnaissance of the Cretaceous and Tertiary Uranium Deposits in the Wasatch Plateau, Utah. TM-127; 10 pp.(1957, August)

A geologic reconnaissance was made of the anomalous radioactive outcrops in the Cretaceous-Tertiary North Horn Formation, the Tertiary Flagstaff Limestone, and the Tertiary Green River Formation of the Wasatch Plateau, Sanpete and Emery counties, Utah. Deposits in the North Horn Formation in the vicinity of Ferron Canyon are confined to upper lacustrine beds of early Paleocene age. Calcium phosphate nodules, fossil bones, and sandstone boulders found as float are hosts to uranium mineralization. Outcrops in the Flagstaff Limestone near Flagstaff peak are only slightly radioactive. However, lithologically favorable beds in the Flagstaff may contain commercial amounts of uranium. Near Axtell, Utah, an outcrop of anomalously radioactive conglomerate is found at the base of the Green River Formation. Bulldozer stripping has exposed this conglomerate for 150 feet and further prospecting in this area may extend this favorable zone. (Auth)

217
Killeen, P.G., and Q. Bristow; Canada Geological Survey, Ottawa, Ontario, Canada

Uranium Exploration By Borehole Gamma-Ray Spectrometry Using Off-the-Shelf Instrumentation. CONF-760316; IAEA-SM-208/4; Exploration of Uranium Ore Deposits, Proceedings of a Symposium, Vienna, March 29-April 2, 1976. International Atomic Energy Agency, Vienna, (pp. 393-414), 807 pp.(1976)

The off-the-shelf instruments, interfaces, borehole probes, cables, winches, recorders, and associated equipment are described and compared. Methods of operation, and of calibration, their relative advantages and disadvantages, and results of borehole measurement are given for both sets of equipment. In addition, 1024 channel gamma-ray energy spectra from the three available borehole probes with NaI(Tl) crystals of sizes 3/4 X 2 in, 3/4 X 3 in, were recorded in the laboratory. The low efficiency of such crystals for high-energy gamma rays is readily apparent from these spectra, and also from spectra recorded in the boreholes in the Bancroft area. Sample recordings of K, U, Th and total count logs were made in the same hole with the three probes, for comparison. An attempt is made to give an appreciation of the problems involved, typical count-rates to be expected, and suggestions are made for future modifications in equipment and techniques to overcome some of the difficulties encountered. (Auth)(MLB)

218
Knapp, K.E., and W.E. Bush; Bendix Field Engineering Corporation, Grand Junction Operations, Grand Junction, CO

Construction of the KUT Test Pits. GJBX-49(76); 31 pp.(1976, September)

A detailed description of the construction of test pits to calibrate spectral logging systems to differentiate between the radiation coming from uranium, thorium, and potassium (KUT) is given. These models are required to calibrate systems used to determine the grade of low-grade uranium deposits. The pits were constructed at the Grand Junction facility from June to September 1974. (PAG)

This report contains 26 figures illustrating the construction and 14 pages of calibration data in the appendices.

219
Knepper, D.H., Jr., and R.W. Marrs; Colorado School of Mines, Department of Geology, Golden, CO; National Aeronautics and Space Administration, Office of University Affairs, Washington, DC

Remote Sensing Aids Geologic Mapping. Proceedings of the Eighth International Symposium on Remote Sensing of Environment, (pp. 1127-1136).(1972, October)

Regional and local geologic mapping can be aided by the proper application of remote sensing techniques. Conventional color and color infrared photos contain a large amount of easily-extractable general geologic information and are easily used by geologists untrained in the field of remote sensing. Other kinds of sensor data used in the study reported in the paper, with the exception of SLAR imagery, were generally found to be impractical or unappropriate for broad-scale general geologic mapping; these data can, however, be effectively applied to specific problems in relatively small areas, but some knowledge of the principles of remote sensing is necessary for the acquisition of the proper data and for subsequent interpretation. (MLB)

220
Komley, L.V., and E.B. Anderson; State Committee on the Use of Atomic Energy, V.G. Khlopin Radium Institute, USSR

The Application of Isotopic Dating Methods for Prospecting and Exploration of Nuclear Raw Materials. IAEA-CN-36/329; Nuclear Power and Its Fuel Cycle, Proceedings of a Symposium, Salzburg, Austria, May 2-13, 1977. International Atomic Energy Agency, Vol. 2, The Nuclear Fuel Cycle, Vienna, (pp. 315-327), 694 pp.(1977, May)

Among the geological methods of forecasting and exploring radioactive raw material deposits, isotopic dating methods determine an important prospect criterion - the time of ore deposition. For a number of studied Paleozoic hydrothermal uranium deposits a long duration (100-160 m.y.) and a complex polychronal character of multistage ore processes are established with the age intervals from 15-30 to 100 m.y. between successive stages. Resolution of methods is assumed to be plus or minus 3 to 5 percent of the age determined using modern mass-spectrometric and analytical techniques. For macroscopically detectable vein-type and coarse-embedded minerals it is necessary to use monomineral fractions of uranium ores corresponding to the particular paragenetic associations. For fine-dispersed submicroscopic metasomatic mineralization it is wise to use only bulk samples. The acquisition of reliable isotopic age data must be based on the results of careful overall mineralogical-geochemical and radiochemical study of uranium mineral ores. (Auth)(MLB)

221
Lendole, A.

Method of Prospecting and Surveying Uranium Deposits. Peaceful Uses of Atomic Energy, Proceedings of the 2nd International Conference, Geneva, August 8-20, 1955. United Nations, Vol. 6, Geology of Uranium and Thorium, (pp. 673-678), 825 pp.(1956)

This method was designed for prospecting of crystalline masses but was adapted to prospecting of sedimentary formations. A semi-systematic survey is used when preliminary surveying (ground or aerial) does not suceed in defining the zone to be investigated. Systematic prospecting defines, by radioactivity measurements, the general appearance and size of the deposit. A counter map is drawn which represents activity by isoactivity curves. Trenches are dug to confirm and define deposits and allow sampling. Upon favorable results of all preceeding work, drilling begins to define the extent of the deposit and supply data on petrography, tectonics, mineralogy, and radioactivity. Mining research then determines the contents, characteristics, and distribution of the mineralization, the paragenesis, and evaluation of the minimum tonnage. (Auth)

222
Liggett, M.A.; Argus Exploration Company, Research Staff, Los Angeles, CA

A Reconnaissance Space Sensing Investigation of Crustal Structure for a Strip from the Eastern Sierra Navada to the Colorado Plateau. E74-10705; 161 pp.(1974, August)

ERTS-1 MSS imagery and subsidiary remote sensing data were evaluated in applications to a broad range of geologic and structural problems in the topographically and climatically diverse terranes of the Sierra Nevada, the southern Basin and Range Province, and the western Colorado Plateau. A detailed ground based study of key field areas was included to determine the origins and significance of geologic and structural anomalies visible in the ERTS-1 MSS imagery. At a broader scale, the ERTS-1 data were used to

study the interrelationship between regional Cenozoic tectonic patterns and other geologic phenomena in the area. High resolution false color compositing of multispectral imagery, edge enhancement printing, and false color spectral ration imaging were developed for effective analysis of ERTS-1 data. (PAG)

223
Linden, A.H., and G. Akerblom; Sweden Geological Survey, Stockholm, Sweden

Method of Detecting Small or Indistinct Radioactive Sources by Airborne Gamma-Ray Spectrometry. Geology, Mining and Extractive Processing of Uranium, Jones, M.J. (Ed.), Proceedings of a Symposium, London, January 17-19, 1977. Institute of Mining and Metallurgy, London, (pp. 113-120), 171 pp.(1976)

The Geological Survey of Sweden has developed a system for airborne radiometric surveying which facilitates the detection of small radioactive sources such as poorly exposed uranium mineralization. By flying at a low height (30m) and measuring over a short time period, the area represented by each measuring station is kept to a minimum. To achieve sufficient precision the entire spectrum between 0.45 and 2.85 MeV is utilized for the calculation of the radiation related to K, U and Th. The results are displayed in the form of a map, on which every measuring station is represented by columns in three colors, one for each element. The map not only indicates point anomalies but also gives a picture of the distribution of the elements over a larger area. It can therefore be of assistance in geological mapping in addition to its application to uranium prospecting. (Auth)

224
Locardi, E., and F. Pantanetti; Comitato Nazionale Energia Nucleare, Fuel Cycle Department, Rome, Italy

Search for Uranium in Italy: Criteria Adopted and Results. CONF-760316; IAEA-SM-208/61; Exploration of Uranium Ore Deposits, Proceedings of a Symposium, Vienna, March 29-April 2, 1976. International Atomic Energy Agency, Vienna, (pp. 545-549), 807 pp.(1976)

Uranium research should follow three steps: 1) selecting the area to be prospected; 2) geological, geochemical, and minerogenetical studies should be carried out in the selected area with the object of limiting the surface and defining the prospecting criteria; 3) ground radiometric prospecting. An organization suitable for carrying out this program requires very limited personnel and money, but quite extensive time. Therefore, this type of fundamental research should ideally be performed by a stable government organization briefed to make an inventory of the natural resources of the country. (MLB)

225
Lovborg, L., and P. Kirkegaard; Danish Atomic Energy Commission, Electronics Department, Riso, Roskilde, Denmark; Danish Atomic Energy Commission, Computer Installation Department, Riso, Roskilde, Denmark

Numerical Evaluation of the Natural Gamma Radiation Field at Aerial Survey Heights. Riso-317; 52 pp.(1975, February)

In computational studies of the count rates to be expected in airborne, radiometric surveys of geological formations, knowledge is required of the aerial gamma radiation field produced by the radioactive minerals in the ground. The data presented in this work permits calculation of the energy and angular distribution of the gamma-ray flux at distances of between 0 and 200 m from a plane, homogeneous ground with known abundances of thorium, uranium, and potassium. A tabulation permitting calculation of the gamma dose rate in the air is also given. The data are applicable to any normal ground material in which uranium and thorium are in secular equilibrium with their respective daughters. Besides, the air density may have an arbitrary variation with the distance to the ground. In calculating the flux of gamma rays that strike an airborne NaI(Tl) detector it is suggested to represent the bottom of the aircraft by an equivalent layer of air. For use in the numerical evaluation of aerial total count rates the angular gamma-ray flux at the point of detection is approximated in accordance with the double-P polynomial expansion method. A detailed tabulation of flux expansion coefficients, calculated for 0.05-MeV wide energy intervals, is presented. To evaluate the differential count rates of high-energy Th-U-K gamma rays, it is convenient to make use of the well-known formulas for a flux of unscattered gamma rays. With this application in view data for insertion in these formulas are also given. (Auth)

226
Maxwell, J.C.; Los Alamos Scientific Laboratory, University of California, Los Alamos, NM

Raw Data Report of Elemental Analyses from Hydrogeochemical and Stream Sediment Samples Taken Near Sterling and Fort Morgan, Northeastern Colorado, December 1976 and January 1977. GJBX-39(77); LA-6740-MS; 27 pp.(1977, March)

Samples were collected from 125 sites near Sterling and Fort Morgan, Colorado, to evaluate the geochemical relationships of water and sediments and seasonal variations to uranium for the South Platte drainage. Samples were analyzed for uranium using fluorometry for the water samples and delayed-neutron counting for sediments and those water samples have more than 10 ppb uranium or interfering elements. Water samples were analyzed for As, Ca, Co, Cu, Cr, Fe, Pb, Mg, Mn, Mo, Ni, K, Si, Na, and Zn using emission spectrometry. The sediment samples were analyzed for Bi, Cd, Pb, Ni, Nb, Sc, Ag, Sn, and W by energy-dispersive x-ray fluorometry. Neutron activation analysis was used to analyze the sediment samples for Al, Sb, As, Ba, Br, Ca, Ce, Cs, Cr, Cl, Co, Cu, Dy, Eu, Ga, Au, Hf, Fe, La, Lu, Mg, Mn, Hg, K, Rb, Sc, Ag, Na, Sr, Ta, Tb, Th, Ti, W, V, Yb, and Zn. The relative errors are approximately 40 percent near the lower detection limits, and less than 10 percent at the concentrations one order of magnitude greater than the detection limits. (PAG)

This report contains only data. Site descriptions and analyses for the water samples are listed in Appendix A. Data for the sediment samples are given in Appendix B. Parameters measured at each sample site during the sampling are listed in Appendix C. Coding used in the Appendices is explained in Appendix D.

227
McDougald, W.D.; AEC, Exploration Division, Grand Junction Office, Grand Junction, CO

Wagon Drilling in the Skull Creek Area, Moffat County, Colorado. RME-80, (Part 1); 15 pp.(1955, April)

The purpose of the drilling was to evaluate the potentialities of a sandstone facies of the Curtis formation by determining the extent of partially developed orebodies, and to establish possible ore guides and controls. The only significant uranium deposits known in the Skull Creek are restricted to a lower sandstone facies of the Curtis formation. Carnotite occurs in lenticular bodies associated with carbonaceous material. Joint systems appear to exercise some control over the localization of secondary minerals in one area. (MLB)

228
McKeown, F.A., and H. Klemic; USGS, Washington, DC

Reconnaissance for Radioactive Materials in Northeastern United States During 1952. TEI-317A; 68 pp.(1953, June)

Reconnaissance for radioactive materials was made in parts of Maine, New York, New Jersey, and Pennsylvania. The primary objective was to examine the iron ore deposits and associated rocks in the Adirondack Mountains of New York and the Highlands of New Jersey. In addition, several deposits known or reported to contain radioactive minerals were examined. The Old Bed in the Mineville district (NY) is the only deposit that may be economically significant. Apatite from Old Bed ore contains as much as 4.9 percent total rare earths, 0.04 percent thorium, and 0.018 percent uranium. Magnetite ore at the Rutgers mine (NY) contains radioactive zircon and apatite. Radioactivity measurements of outcrops and dump material show that the ore contains from 0.005 to 0.010 percent equivalent uranium. One sample of lean magnetite ore contains 0.006 percent equivalent uranium. The Canfield phosphate mine (NJ) was originally opened as a magnetite mine but contains about 35 percent apatite. Monazite is also present in the ore. The apatite and monazite are radioactive. Garnet-rich zones in the Benson Mines (NY) magnetite deposit contain as much as 0.017 percent equivalent uranium. Most of the rock and ore, however, contains about 0.005 percent equivalent uranium. Available data indicate that the garnet-rich zones are enriched in radioactive allanite. A shear zone in the Kittatinny limestone of Cambrian age at the Mulligan quarry (NJ) contains uraniferous material. Radioactivity anomalies elsewhere in the quarry and in adjacent fields indicate that there may be other uraniferous shear zones. Assays of samples and measurements of outcrop radioactivity indicate that the uranium content of these zones is low; samples contain from 0.008 to 0.068 percent equivalent uranium. The anomalies, however, may indicate greater concentrations of uranium below surficial leached zones. The Chestnut Hill-Marble Mountain area (PA and NJ) contains radioactivity anomalies for about 2 miles along the strike of the contact of pre-Cambrian

Pickering gneiss and Franklin limestone formations. In places this contact is injected with pegmatite, which probably was the source of the radioelements. At Marble Mountain, a nearly continuous anomaly extends for about 1500 feet. Samples from part of this area contain as much as 0.044 percent equivalent uranium and 0.005 percent uranium. Radioactive hematite and florencite in which thorium may have substituted for cerium, are the only radioactive minerals observed in the Marble Mountain area. (Auth)(PAG)

229
Miller, L.J., D.F. Spencer, and E.W. Oertell; AEC, Grand Junction Office, Exploration Branch, Grand Junction, CO

Exploratory Drilling on Frey Point Mesa, White Canyon Area, San Juan County, Utah. TM-125; 18 pp.(1957, June 26)

Frey Point Mesa is on the west flank of the Monument upwarp where exposed sedimentary rocks range from Permian to Jurassic in age. Exploratory drilling consisted of 128 diamond drill holes totaling 16,191.1 feet. Twelve diamond drill holes penetrated uranium deposits of ore grade; twenty-two other drill holes encountered deposits of sub-ore grade. Uranium deposits in the White Canyon No. 1 and Saddle channel localities on Frey Point Mesa are localized in Shinarump clastics containing an abundance of clayey and carbonaceous material deposited in paleostream channels cut into the underlying Moenkopi formation. Uranium minerals include uraninite, uranopilite, johannite, uranophane, and metatorbernite. These occur as replacements of carbonaceous material and as disseminations in sandstone. (Auth)(PAG)

230
Minatidis, D.G., and R.M. Slatt; Memorial University of Newfoundland, Department of Geology, St. John's Newfoundland (Canada)

Uranium and Copper Exploration By Nearshore Lake Sediment Geochemistry, Kaipokok Region of Labrador. Journal of Geochemical Exploration 5:135-144.(1976)

Uranium and copper analyses of nearshore sediments from 24 lakes in the Kaipokok region of Labrador have allowed definition of zones across glacial drift and lake-covered terrain which are enriched in these elements. Some zones are extensions of known U and Cu mineralization, but others had not been previously found by airborne surveys or lake water geochemistry. Further exploration appears warranted in the zones that are defined. Geochemical analysis of nearshore lake sediments collected systematically around the periphery of several lakes within a mineralized area is a rapid, informative exploration method for delineating local U and Cu rich areas which can be used as a follow-up to reconnaissance level sampling. (MLB)

231
Moore, G.W., and J.G. Stephens; USGS, Washington, DC

Reconnaissance for Uranium-Bearing Carbonaceous Rocks in California and Adjacent Parts of Oregon and Nevada. USGS Circular 313; 8 pp.(1954)

A reconnaissance in California and parts of Oregon and Nevada was conducted in search of new deposits of uranium-bearing carbonaceous rocks. The principal localities found in California where uranium occurs in coal and the uranium content of the coal are: Newhall prospect, Los Angeles County, 0.020 percent; Fireflex mine, San Benito County, 0.005 percent; American Lignite mine, Amador County, 0.004 percent; and Tesla prospect, Alameda County, 0.003 percent. An oil-saturated sandstone near Edna, San Luis Obispo County, contains 0.002 percent uranium. (Auth)

Six tables of data are included.

232
Morris, W.A.; Los Alamos Scientific Laboratory, Los Alamos, NM

Hydrogeochemical and Stream Sediment Reconnaissance of the National Uranium Resource Evaluation Program - Progress Report - July-September 1976. LA-6644-PR; GJBX-12(77); 22 pp.(1977, January)

Water and/or sediment samples have been collected from some 47,000 sample locations covering about 504,000 square kilometers which represents 19 percent of the assigned area. The first commercial, helicopter-borne sampling contract in Alaska took place during this part of the program where 4,468 locations were sampled

over an area of 94,000 square kilometers. Thus far in the program, uranium determinations have been made for some 12,000 water samples by fluorimetry and for over 15,000 sediment samples by delayed-neutron counting. The main effort has been directed toward completing all outstanding commercial sampling contracts, and analyzing the backlog of water and sediment samples. (MLB)

233
Morse, R.H.; Toronto, Ontario, Canada

Radon Counters in Uranium Exploration. CONF-760316; IAEA-SM-208/55; Exploration of Uranium Ore Deposits, Proceedings of a Symposium, Vienna, March 29-April 2, 1976. International Atomic Energy Agency, Vienna, (pp. 229-239), 807 pp.(1976)

Rapid analytical techniques are available for uranium, radium and radon, each of which is characterized by a different geochemical behavior and each of which is absolutely specific for uranium. An efficient geochemical exploration program will be based on a judicious combination of these elements. The battery-operated digital alpha scintillometer combines portability with high sensitivity. Radon and radium can be determined in the field. Radon 220 is recognized by a rapid drop in count-rate owing to its 54.5-s half-life. At the detailed level of exploration radon in soil gas provides a useful supplement to ground gamma scintillometry. Readings as low as 20 counts/min or lower are significant. High readings due to especially permeable soils are characterized by rapidly falling count-rates because of dilution by Radon 220. Uranium anomalies are characterized by steady or rising count-rates. Counting beyond the first minute and monitoring any changes is essential. Diurnal radon variations are not critical in Canada. An example is provided from the Bancroft area which compares radon to soil to ground gamma scintillometry. The radon survey shows more detail, in agreement with the geology, than the scintillometer. (Auth)

234
Nelson, J.M., and P.F. Narten; USGS, Washington, DC

Reconnaissance of Radioactive Rocks of Maine. TEI-68; 43 pp.(1951, December)

The state of Maine was traversed with car-mounted Geiger-Mueller equipment and the radioactivity of approximately 4,600 miles of road was logged. The maximum equivalent uranium content of the most radioactive rocks was 0.008 percent. A 1,400-square-mile abnormally radioactive province in SW Maine was outlined. Cumulative frequency distribution curves were drawn to show the distribution of outcrops at various levels of radioactivity, and straight-line extensions were made to show the maximum probable grade for various rock types and areas in Maine. A maximum grade of 0.055 percent equivalent uranium is predicted for the entire state. (Auth)(PAG)

235
Nichols, C.E., V.E. Kane, M.T. Browning, and G.W. Cagle; Oak Ridge Gaseous Diffusion Plant, Oak Ridge, TN

Northwest Texas Pilot Geochemical Survey. K/UR-1; 227 pp.(1976, September 30)

Samples of stream sediment, stream water, well water, and ash of plants in northwest Texas were analyzed for approximately 25 parameters. The samples were collected in the outcrop area of the Blaine Formation, the Whitehorse and Cloud Chief Group, and the Quartermaster Group (all Permian); the Dockum Formation (Triassic); and the Ogallala Formation (Tertiary). The most valuable sample type for identifying potential uranium mineralization in northwest Texas is well water. It is the most reliable for outlining both uranium deposits and, at a wider spacing, a potential uranium district. Of the other sample types, stream sediment is more available than stream water. The most useful determinations in groundwater from the 5 potentially mineralized areas are uranium, sulfate, molybdenum, selenium, alkalinity, arsenic, conductivity, and vanadium. Elements anomalous in stream sediments associated with a potentially mineralized area in the Triassic rock are lead, manganese, barium, scandium, and selenium. Anomalies in stream water associated with the postulated mineralization in the Triassic rock are alkalinity, uranium, selenium, and arsenic. A comparison of analyses of uranium in stream sediment by neutron activation and fluorescence spectroscopy is used to indicate areas where anomalies in some elements may result from resistate minerals. A geochemical model of uranium and associated trace elements in groundwater associated with roll-type mineralization is proposed for the reconnaissance-scale sample spacing of approximately 5 km (3 mi). A zone of trace element

mobilization is indicated by high concentrations of uranium, sulfate, carbonate, total alkalinity, and selenium on the oxidized side of a redox front. The decrease in these parameters on the reduced side implies that these species are precipitated between the wells indicated. Molybdenum may be to the side of, or farther down dip than, the center of the geochemical cell. Arsenic is most valuable for its regional halo around areas of mineralization. Based on the geochemical model of trace elements and groundwater, 5 areas of potential uranium mineralization are identified in the pilot survey area: 1 in the Quartermaster Formation, 1 in the Dockum Group, and 3 in the Ogallala Formation. The areas are described with reference to a weighted cluster plot of multielement data and contour maps of several chemical parameters. (Auth)(PAG)

The following appendices are included in the report: Appendix A: Stream Sediment; Appendix B: Stream Water; Appendix C: Well Water; Appendix D: Trees; Appendix E: Field Form; Appendix F: Precipitation and Runoff; Appendix G: Comparison of Original Samples with Resamples; Appendix H: Summary of Measurement Control; Appendix I: Computer Code List for URE Variables; Appendix J: Microfiche of Laboratory and Field Data

236
Noble, E.A., and E.C. Annes, Jr.; AEC, Grand Junction Office, Exploration Division, Grand Junction, CO

Reconnaissance for Uranium in the Uinta Basin of Colorado and Utah. RME-94; 22 pp.(1957, January)

A geologic reconnaissance consisting chiefly of ground reconnaissance in areas of known uranium occurrence, supplemented by airplane reconnaissance of an area of about 5,000 square miles and about 240 linear miles of rim flying in selected areas, was made of the Uinta Basin, NE Utah and NW Colorado. Weak uranium mineralization is widespread throughout in rocks ranging in age from Permian to Eocene. Carbon is generally associated with uranium-mineralized rock, although uranium minerals also occur in open spaces along faults and in joints in the absence of carbon. All uranium minerals identified are secondary. Wide differences in equilibrium are shown by assays; chemical assays commonly show more uranium than radiometric assays. Ratio of uranium to vanadium differs widely from place to place and within single deposits. (Auth)(PAG)

237
Olsen, C.E.; Los Alamos Scientific Laboratory, Los Alamos, NM

Uranium Hydrogeochemical and Stream Sediment Pilot Survey of the Estancia Valley, Bernalillo, Santa Fe, San Miguel, and Torrance Counties, New Mexico. LA-6650-MS; GJBX-21(77); 84 pp.(1977, January)

Water samples from 534 locations and sediment samples from 2936 locations were taken over a 7770-km2 area of the Estancia Valley, a closed topographic basin having a well-developed salt playa, and analyzed for uranium. Uranium concentrations in the valley waters range from undetectable to a high of 334 ppb. Statistical analysis of the water data shows that the uranium content of the water definitely depends in part on the source type and, apart from playa waters, ranges in average value from 1.78 ppb for water from artificial ponds to 5.23 ppb for well water. The highest value of uranium in water is found in a playa sample. This high value appears to be the result of evaporative concentration of uranium but may also reflect higher than average uranium contents in some of the closely adjacent rocks of the valley. High values of uranium in water also occur associated with high uranium values in sediment. Screen analysis of 100 selected sediment samples indicates that the -100 mesh fraction, used ultimately as a standard throughout the survey, is a good choice for the determination of uranium in sediments. The uranium content of the sediment samples varies from a minimum of 0.7 ppm to a maximum of 10.7 ppm. Statistical analyses of the data from all five of the different types of sediment source that were sampled show that the average uranium concentration is essentially independent of the source type in this area. These five sediment source types are wet streams, springs, and ponds and dry streams and ponds. Using all the sediment data, a sharply peaked distribution is obtained with an average uranium concentration of 2.92 ppm and a standard deviation of 0.73 ppm. Using a criterion of three standard deviations above the mean for the anomaly threshold level, 55 of the 2936 locations sampled for sediment have anomalous uranium concentrations. Generally, these locations occur in areas having known radiometric highs or in formations found to be uraniferous in other areas. This report provides

listings of all the basic data utilized and plots of numbered sample locations at 1:125,000-scale. It also includes a geologic map of the area with overlays showing the drainage pattern, the sample points (unnumbered), and the uranium concentrations found in the water and the sediments, all at 1:250,000 scale. (Auth)(PAG)

238
Peirce, H.W.; Arizona Bureau of Mines, Tucson, AZ

Arizona Uranium - The Search Heats Up. Fieldnotes from the Arizona Bureau of Mines 7(1):1-4.(1977)

At least 150 sq miles in southwest Yavapai County and northeast Yuma County, Arizona are being explored for new uranium occurrences. An outcrop was discovered in this region in 1955 with the aid of an airborne scintillation counter by T.R. Anderson. The Anderson mine host rocks are fine-grained, lake bed sedimentary rocks, about 200 feet thick and overlain by younger sediments and a thin basalt flow. The lake beds are fossiliferous, faulted, folded, locally silicified, and contain lensing lignitic units. The principal uranium mineral is carnotite; the source is unknown. (PAG)

239
Peterson, A.M.; AEC, Grand Junction Operations Office, Salt Lake Branch, Salt Lake City, UT

Summary of the Airborne Radiometric Survey of the Southern California Project, Southeastern California and Southwestern Arizona. RME-2080; 10 pp.(1956, July)

A scintillation counter with a 5-inch crystal mounted in a 135-horsepower, 2-place, fixed-wing airplane was used in the airborne survey. Flight lines were governed by terrain; neither rim nor grid methods of flying were strictly employed because of the highly dissected, blocky, serrate topographic features of the southeastern California and southwestern Arizona project area. Precambrian schists, gneiss, granite; Paleozoic sediments and metasediments; Mesozoic intrusives, metasediments; and Tertiary sediments and volcanics constitute the rock types flown. Flight lines were spaced in accordance with coverage requirements when possible. A spacing of about 200 feet, at an average elevation of between 50 to 100 feet, was maintained for 30-50 percent coverage. All discernible faults, contacts of plutonic and metamorphic rocks, many granitic and schistose areas, iron-stained and discolored areas, mines and prospects were given from 25-75 coverage. Twenty four anomalies were detected; six show uranium minerals, eleven were not ground checked, and seven failed to reveal any uranium minerals. (PAG)

240
Philbin, P., and F.E. Senftle; USGS, Washington, DC

Field Activation Analysis of Uranium Ore Using Californium 252 Neutron Source. Transactions of the American Institute of Mining, Metallurgical, and Petroleum Engineers 250:102-106.(1971, June)

A field neutron activation analysis technique suitable for determining uranium in ores has been tested. The method is based on the measurement of the 74.7 keV gamma ray from U 239. When the thorium uranium ratio is greater than one or the vanadium is greater than 1 percent, a low uranium analysis is obtained. No satisfactory correction for thorium has been found, but a correction for vanadium can be determined. For ore containing greater than 0.01 percent uranium, the uranium can be determined with an accuracy of about 10 percent which is quite adequate for a field exploration technique. (Auth)

241
Pochet, F.R.; CEA, Direction des Productions, Departement des Recherches et Prospections Minieres, Chatillon-sous-Bagneux, France

Le Developpement des Diagraphies dans les Forages de Recherche et d'Exploitation Miniere an Commissariat a l'Energie Atomique. CONF-760316; IAEA-SM-208/33; Exploration of Uranium Ore Deposits, Proceedings of a Symposium, Vienna, March 29-April 2, 1976. International Atomic Energy Agency, Vienna, (pp. 353-366), 807 pp.(1976)

Since 1960 continuous logs using motor winches and direct analogue recording have been developed simultaneously with a drive to find uranium in sedimentary media. At that time natural gamma activity logs were combined with electrical logs to obtain a lithological interpretation of the holes and establish correlations between them. For several years the

Commissarist a l'energie atomique (CEA) has been replacing the electrical logs by nuclear logs that can be made within the protective tubing. Thus, neutron-neutron porosity logs have become routine like natural radioactivity logs, and gamma-gamma density logs are also being developed. During the same period all equipment has been modified considerably to improve data acquisition and processing. Direct recording on magnetic tapes, in particular, has come into general use and is bringing about a complete transformation in the use of logs, thanks to the manifold possibilities of processing it offers. (Auth)

242
Podwysocki, M.H., J.G. Moik, and W.C. Shoup; NASA, Goddard Space Flight Center, Greenbelt, MD)

Quantification of Geologic Lineaments by Manual and Machine Processing Techniques. NASA-TM-X-70951; 23 pp.(1975, July)

A large amount of variability in mapping by operators suggested a need for the standardization of mapping techniques. Two methods of machine-aided mapping were tested. One consists of computer (digital) processing of CCT's using edge enhancement algorithms. The other employs a television (analog) scanning of an image transparency which superimposes the original image and one offset in the direction of the scan line. Many more linear features were detected by machine processing than are detected by the unaided eye. There is agreement between the two processing techniques, and the features seen are related to linear features on the ground. A comparison of a processed LANDSAT image and a map of lineaments created from large-scale photography indicated a concurrence in directions of individual lineaments, although many more features are seen by the enhancement. (Auth)(PAG)

243
Popenoe, P.; USGS, Washington, DC; AEC, Division of Biology and Medicine, Civil Effects Test Operations, Washington, DC

Aeroradioactivity Survey and Areal Geology of Parts of East-Central New York and West-Central New England. CEX-59.4.14; 39 pp.(1964, October)

An airborne gamma-radiation survey of parts of New York, Massachusetts, New Hampshire, and Vermont indicates that a wide range of natural radioactivity exists and that the levels are closely related to the type of bedrock underlying glacial material, and subordinately to [illegible] glacial material. The area was traversed with parallel flight lines flown 500 feet above the ground and spaced at 1 mile intervals. Continuous aeroradioactivity profiles were obtained with scintillation detection equipment installed in a twin-engine aircraft. The natural gamma radioactivity in the project area ranges from less than 100 cps to 1150 cps, averaging about 500 cps. Rocks of both sedimentary and igneous origin produced high and low levels of radioactivity. Three large areas containing rocks of moderate to high radioactivity are present: one is associated with clastic rocks of Devonian age in the Helderberg Plateau and foothills of the Catskill Mountains; another is associated with phyllite and slate of Cambrian and Ordovician age in the Taconic Mountains and foothills; and a third is associated with a broad belt of phyllite, micaceous quartzite, and intrusive igneous rock, chiefly of Devonian age, in New Hampshire and east-central Massachusetts. Low radioactivity is associated with a large massif of anorthosite in the Adirondack Mountains; large areas of the Precambrian complex of the Green and Adirondack Mountains, a broad belt of Cambrian, Ordovician, and Devonian schist, gneiss, and amphibolite in eastern Vermont; igneous rocks of the Oliverian Plutonic Series in New Hampshire and Massachusetts, and glacial lacustrine deposits along the Hudson and Connecticut Rivers. (Auth)(PAG)

244
Popenoe, P.; U[illegible]ington, DC; AEC, Division of Biol[illegible]Medicine, Civil Effects Test Operations, Was[illegible]ngton, DC

Aeroradioactivity Survey and Areal Geology of Parts of Southeastern New York and Southern New England. CEX-58.4.6; 31 pp.(1966, September)

An airborne gamma-radiation survey of Connecticut, Rhode Island, and parts of New York and Massachusetts indicates that a wide range of natural radioactivity exists and that the radioactivity is closely related to both the type of bedrock underlying glacial drift, and to the glacial drift. The area was traversed with east-west flight

lines flown 500 feet above the ground and spaced at 1 mile intervals. Continuous aeroradioactivity profiles were obtained with scintillation detection equipment installed in a twin-engine aircraft. The natural gamma radioactivity measured in the southeastern New York and southern New England area ranges from 200 to 1500 cps. The radioactivity level is directly relatable to the uranium, thorium and potassium-40 content of the surface material. The Quincy Granite of Rhode Island has the highest radioactivity of any rock (1500 counts per second). Rocks of higher than average radioactivity include the Storm King Granite, a south-central belt of the Hartland Formation and associated granitic gneiss, granitic gneiss in the cores of the domes of eastern Connecticut, and large areas of granitic gneiss in eastern Connecticut and Rhode Island. Rocks of lower than average radioactivity include the mafic and ultramafic rocks of the Cortlandt Complex, areas of metamorphic rock in the Housatonic and Berkshire Highlands, diabase and basalt of Triassic age, the plagioclase and amphibolitic gneiss of eastern Connecticut, the Glastonbury Gneiss north of Manchester, Connecticut, the Plainfield Formation, glacial lacustrine deposits in central Connecticut, and glacial outwash and marsh deposits on Long Island and in the Narragansett Basin. (Auth⁄PAG)

245
Popenoe, P.; USGS, Washington, DC; AEC, Division of Biology and Medicine, Civil Effects Test Operations, Washington, DC

Aeroradioactivity Survey and Areal Geology of the Denver Area, Colorado. CEX-59.4.26; 26 pp.(1966, July)

An airborne gamma-radiation survey of 6500 sq mi near Denver, Colorado was made by the USGS for the AEC. Continuous radioactivity profiles were obtained with scintillation detection equipment installed in a twin-engine aircraft. The area was traversed with parallel east-west flight lines spaced at one mile intervals and flown 500 feet above the ground. All of the area surveyed lies in the Colorado Piedmont section of the Great Plains physiographic province which is underlain by Paleozoic, Mesozoic, and Cenozoic sedimentary rocks and Quaternary surficial deposits. The natural gamma radioactivity in the Denver area ranges from 300 to 1550 cps. Sedimentary rocks and alluvial material containing debris from the crystalline rocks of the Front Range have relatively high radioactivity except where deeply weathered. Among these rocks are the upper part of the Dawson Formation, and alluvium along the creeks that originate in the Front Range. Medium radioactivity characterizes most of the shaly and sandy sedimentary rocks such as the Lykins, Ralston Creek, Niobrara, Laramie, Denver, and Arapahoe formations, and the Fox Hills Sandstone, Pierre Shale, lower part of the Dawson Formation, and loess. Low radioactivity characterizes the Dakota Group and Lyons Sandstone exposed in the hogbacks near the Front Range, dune sand along the South Platte River, and deeply weathered upland gravel west of Denver. (Auth⁄PAG)

246
Redmon, D.E.; US Bureau of Mines, Denver, CO

Exploratory Drilling Practices and Costs at Western Uranium Deposits. Information Circular 7944; 68 pp.(1960)

Results of studies of several drilling methods currently used in the search for uranium deposits in sedimentary formations from surface drill sites, and a description of drilling with wire-line equipment from an underground location in metamorphic rocks are presented. The studies were conducted in the Colorado Plateau area and in northwestern New Mexico and Wyoming. The data were obtained from drilling contractors and the managerial staffs of mining companies and equipment manufacturers. Types of drilling, methods of core recovery, non-core drilling techniques, and exploratory practices at numerous locations on the Colorado Plateau are reviewed. (PAG)

247
Reichardt, J.; Kaman Sciences Corporation, Colorado Springs, CO

Development of a Neutron Logging Tool for Uranium Exploration. GJBX-18(76); 35 pp.(1976, October 1)

A neutron logging tool with the capability for uranium exploration using the Delayed Fission Neutron technique was developed and demonstrated. The tool may be used to make stationary neutron assays of uranium ore grade or moving logs in either the neutron or natural gamma mode. The neutron count data show excellent correlation to the 0.01 percent U3O8 level. Data from barren zones indicate that oxygen

radiation can be used to calibrate the neutron generator output, however, the tool must be tested and calibrated in uranium free formations with known chemical and physical properties. Testing demonstrated the tool to be in proper operating condition and useful for uranium exploration. Instrument specifications and operational characteristics of the system are given. (PAG)

248

Rodriguez Torres, R., R. Yza Dominguez, R. Chavez Aguirre, and S.E. Constantino H.E.: Instituto Nacional de Energia Nuclear, Programa de Exploraciones y Explotacion Minera, Mexico, D.F., Mexico

Rocas Volcanicas Acidas y Su Potencial como Objetivos para Prospectar Uranio. CONF-760316; IAEA-SM-208/59; Exploration of Uranium Ore Deposits, Proceedings of a Symposium, Vienna, March 29-April 2, 1976. International Atomic Energy Agency, Vienna, (pp. 601-623), 807 pp.(1976)

The geographical distribution of recent Mexican volcanic rocks is continuous; the older formations are dispersed in isolated outcrops. Continental volcanic events, acidic and basal, took place in the Cenozoic, Mesozoic and Paleozoic; basic submarine volcanism predominated in the Mesozoic, Paleozoic and late Precambrian. Access to the Sierra Madre Occidental, a circum-Pacific mountain range covered by rhyolitic rocks, is limited, which restricts the sections studied. Calderas, sources of volcanic emission and preliminary litho-stratigraphic sections have been delimited on the eastern edge of the range. Subduction by the ocean magmatized the continent from the Permian onwards, extravasating and depositing cyclically various magmata through inverted and normal cortical throws. The Sierra Pena Blanca (Chihuahua) section consists of epiclastic and pyroclastic rocks. A calcareous conglomerate is overburdened by alternate basal tuffs and imbricates, forming five units. In the uraniferous district of the Sierra Pena Blanca the hydrothermal alteration argillitized both components of the "Nopal" formation. Primary minerals (pitchblende) are found together with silicification. Leaching favours secondary mineralization (uranium silicates) associated with opals. After extrapolation of the features, the following are considered worth-while objectives: the faces, offsets and prolongations of the Sierra Madre Occidental and the southern volcanic mesetas south of the Mexican Transcontinental Rift. Similar objectives of Mesozoic or Paleozoic age exist in central and southern Mexico. Possible objectives for uranium are: The acidic volcanic rock of the southern and south-western United States of America, the circum-Pacific acidic volcanic rocks of North America and the acidic volcanic mesetas of Central America and in the Andes. (Auth)

249

Rossiter, A.G

Stream-Sediment Geochemistry as an Exploration Technique in the Westmoreland Area, Northern Australia. Bureau of Mineral Resources Journal of Australian Geology and Geophysics 1:153-170.(1975)

Orientation geochemical studies indicate that stream-sediment sampling is a potentially powerful exploration technique in the Westmoreland region of Northern Australia. Uranium, copper, tin, and lead mineralization can all be detected by the use of a combination of sieved samples and heavy-mineral concentrates. Vein-type uranium deposits occur in a variety of rock units in the area. The secondary dispersion of uranium from these deposits appears to be dominantly chemical, and sieved samples are very effective in prospecting; heavy-mineral concentrates rarely contain detrital uranium minerals and consequently are less efficient. Arsenic is a useful pathfinder element for uranium mineralization in some instances. Copper deposits are encountered in both the granites and the basic igneous rocks of the area. Heavy-mineral concentrates are particularly sensitive in tracing copper mineralization. At several localities no anomalous copper was detected chemically in sieved samples, whereas malachite was conspicuous among the heavy minerals Tin deposits occur in pneumatolytically altered zones within high-level granites and acid volcanic rocks. The chemical analysis of sieved samples and the optical examination of heavy-mineral concentrates for cassiterite are equally effective in prospecting for tin. If sieved samples are preferred, lithium and tungsten are useful pathfinder elements. Lead mineralization of syngenetic origin is associated with the dolomitic rocks of the region. The analysis of heavy-mineral concentrates appears to have great potential in exploration for this type of deposit, but the technique has yet to be fully evaluated. Near mineralization sieved samples contain anomalous lead and zinc; minor enrichment of copper also

occurs. Scavenging by secondary manganese compounds leads in places to false zinc anomalies, so great care is required in the interpretation of 'anomalous' zinc values. (Auth)

Extensive tabular data is included in the report.

250
Ruzicka, V.; Canada Geological Survey, Ottawa, Ontario, Canada

Uranium Resources Evaluation Model as an Exploration Tool. CONF-760316; IAEA-SM-208/1; Exploration of Uranium Ore Deposits, Proceedings of a Symposium, Vienna, March 29-April 2, 1976. International Atomic Energy Agency, Vienna, (pp. 673-682), 807 pp.(1976)

The first three steps in resource evaluation coincide with those usually taken in the preparatory stage for uranium exploration. The first stage in any uranium exploration project is devoted to collection of materials and geological studies on broader prospective areas. This step is computerized and thus capable of efficient and systematic collecting and retrieving data from diversified sources and computer-based data banks. Another stage in exploration activity is the selection of exploration targets. The second step of the model culminates with the delineation of favorable areas. During this step, documents and data are produced that can serve as a base for decision-making in exploration methodology, in selection of technique, etc. The reconnaissance stage in exploration coincides with the third step requiring field evidence and additional data for the resource evaluation. The preliminary evaluation techniques in exploration usually employ simple tests and estimations based on scarce data. The simplified method of resource computation, as indicated in the fourth step of the evaluation model, should generally fulfil requirements of the analogous stage in exploration. Furthermore, resources evaluation can be used, applying the quantification of geological data as a basis for the formulation of uranium exploration strategy. Thus, the uranium resources evaluation model can directly serve as an exploration tool. (MLB)

251
Saukoff, A.A.

Radiohydrogeological Method in Prospecting for Uranium Deposits. Peaceful Uses of Atomic Energy, Proceedings of the 2nd International Conference, Geneva, August 8-20, 1955, United Nations, Vol. 6, Geology of Uranium and Thorium, (pp. 756-759), 825 pp.(1956)

The radiohydrogeological method of prospecting for uranium deposits is based on the ability of the element and its disintegration products, radium and radon, to dissolve in natural waters and migrate with them. Radiohydrogeological (hydrogeochemical) investigations consist of three main kinds of work: sampling the waters, determining the content of radioactive elements in them, and interpreting the results. The development of this method became possible as a result of theoretical conclusions on the migration of elements. The use of the hydrogeochemical method has led to the discovery of new ore-bearing districts and deposits, as well as new orebodies in deposits already being mined or prospected in the USSR. (MLB)

252
Saunders, D.F., G.E. Thomas, F.E. Kinsman, and D.F. Beatty; Texas Instruments Incorporated, Dallas, TX

ERTS-1 Imagery Use in Reconnaissance Prospecting: Evaluation of the Commercial Utility of ERTS-1 Imagery in Structural Reconnaissance for Minerals and Petroleum. U1-702700-F; 129 pp.(1973, December)

Five study areas in North America (Montana; Colorado; New Mexico-West Texas; Superior Province, Canada; and North Slope, Alaska) were chosen to provide a representative variety of types of economic geology, physiography, and climates. Sixty-five percent of the vein type uranium deposits in Area 1 are found on or within 4 miles of ERTS linears, whereas only 46 percent of the lignite deposits are apparently related to linears. These results seem reasonable due to the probable different origins of the deposits. In Area 2 about 82 percent of the uranium deposits are located within 4 miles of a linear. The sandstone-type deposits are more scattered and do not show such a close relationship to the linear and curvilinear features. About 55 percent of these deposits are located within 4 miles of a linear. Some 52 percent of the uranium deposits in Area 3 lie within 4 miles of a linear. This agrees quite well with the comparative figure for sandstone deposits in Area 2 and reflects the stratigraphic control of the Area 3 sandstone deposits which predominate. The Elliot Lake area in the southwest corner of Area 4 contains the largest uranium reserves of Canada.

Although these deposits are apparently stratigraphically controlled, ERTS imagery might be used for detailed photogeologic mapping that could help greatly in elucidating the structural relationships of the ore bearing strata. There is not enough information on uranium mineral localities in Alaska to draw any valid conclusions about structural control, but it is believed that the same general structural concepts may apply. In all areas ESE linears appear to be favorable areas for prospecting. In the Laramide areas NE trends appear favorable, while SE trends are mineralized in the Precambrian. The control on deposition appears to be predominately stratigraphic and this is indicated even stronger in the uraniferous lignites. (PAG)

253
Schnabel, R.W., and R.C. Vickers; USGS, Washington, DC

Reconnaissance of the Clinton Formation in New York, Pennsylvania, Maryland, and New Jersey. TEM-434; 12 pp.(1953, January)

The Clinton Formation consists mainly of sandstone and shales in Pennsylvania, Maryland, and New Jersey and of sandstones, shales, and limestones in New York. There are several beds of oolitic hematite in the Clinton formation, a few inches to several feet thick. Samples at 31 localities were examined radiometrically and showed no abnormal radioactivity. The maximum radioactivity was 0.004 percent equivalent uranium, and no sample contained more than 0.001 percent uranium. (PAG)

254
Schneid, E.J., F.R. Swanson, E.A. Kamykowski, and A. Mendelsohn; Grumman Aerospace Corporation, Research Department Bethpage, NY

Airborne Detector Improvement.
GJBX-40(77); RE-538; 64 pp.(1977, March)

Experimental and theoretical comparisons were conducted between a large volume NaI detector and a large volume collimated Phoswich detector. Airborne Phoswich detector systems can provide approximately a factor of two increase in detection sensitivity for uranium when compared to existing NaI systems. Laboratory experiments were conducted to establish the ability of the existing Phoswich detector to provide background and Compton distribution suppression in the 1-3 MeV energy region of interest for this application. These measurements also serve to verify the analytical models used for Phoswich detector design studies. During this study, the two detectors were flown to obtain simulataneous measurements of the potassium, uranium, and thorium concentrations in the vicinity of Lake Winnipesaukee, New Hampshire. The correlation of the flight results with the experimental and computer predictions support the conclusion that a Phoswich detector system can provide approximately a factor of two increase in detection sensitivity. (Auth)

255
Senftle, F.E., R.M. Moxham, A.B. Tanner, G.R. Boynton, P.W. Philbin, and J.A. Baicker; USGS, Reston, VA; Princeton Gamma-Tech., Princeton, NJ

Intrinsic Germanium Detector Used in Borehole Sonde for Uranium Exploration. USGS Open File Report 76-452; 28 pp.; Nuclear Instruments and Methods 138(2):371-380.(1976)

A borehole sonde using a 200 mm2 planar intrinsic germanium detector, mounted in a cryostat cooled by removable canisters of frozen propane, has been constructed and tested. The sonde is especially useful in measuring X- and low-energy gamma-ray spectra (40-400 keV). Laboratory tests in an artificial borehole facility indicate its potential for IN-SITU uranium analyses in boreholes irrespective of the state of equilibrium in the uranium series. Both natural gamma-ray and neutron-activation gamma-ray spectra have been measured with the sonde. Although the neutron-activation technique yields greater sensitivity, improvements being made in the resolution and efficiency of intrinsic germanium detectors suggest that it will soon be possible to use a similar sonde in the passive mode for measurement of uranium in a borehole down to about 0.1 percent with acceptable accuracy. Using a similar detector and neutron activation, the sonde can be used to measure uranium down to 0.01 percent. (Auth)

256
Sharp, R.R., Jr., W.A. Morris, and P.L. Aamodt; Los Alamos Scientific Laboratory, Los Alamos, NM

Hydrogeochemical and Stream Sediment Survey of the National Uranium Resource Evaluation Program - Progress Report -

Januray - March 1976. LA-6369-PR; GJBX-39(76); 54 pp.(1976, June)

The fourth quarter of progress in which the Los Alamos Scientific Laboratory has been involved in the Hydrogeochemical and Stream Sediment Reconnaissance for uranium as part of the National Uranium Resource Evaluation program sponsored by the U.S. Energy and Research Development Administration is described. The region assigned to the LASL includes New Mexiico, Colorado, Wyoming, Montana, and Alaska. Work under the first commercial contract let by the LASL for water and sediment sample collection was completed during this quarter (January - March, 1976), which involved the sampling of 2000 locations over a 20,000 sq. kilometers area in southwest New Mexico. Three other contracts of similar size have been let, one each in Colorado, Wyoming and New Mexico. The samples taken during the reconnaissance are being analyzed at the LASL, and the data results should be open filed through the ERDA Grand Junction Office in the near future. Constant updating of sampling techniques and equipment is being carried out both by the LASL and its sampling contractors. (MBW)

257
Sharp, R.R., Jr., W.A. Morris, and P.L. Aamodt; Los Alamos Scientific Laboratory, Los Alamos, NM

Uranium Hydrogeochemical and Stream Sediment Reconnaissance Data Release for the New Mexico Portions of the Douglas, Silver City, Clifton, and Saint Johns NTMS Quadrangles, New Mexico/Arizona. GJBX-69(78); LA-7180-MS; 123 pp.(1978, March)

Water and stream sediment samples were collected in New Mexico from the Mexico border north to Interstate 40 (north of 35 degrees N latitude) and from 107 degrees 30 minutes W longitude west to the New Mexico/Arizona state line. The sampling was done from south to north from January to July 1976 at a nominal density of one sample location per 10 square kilometers. This report presents only the data from locations west of 108 degrees W longitude-the New Mexico portions of the Douglas, Silver City, Clifton, and Saint Johns quadrangles. The number of water samples and sediment samples, respectively, collected in each quadrangle were: Douglas, 181 and 237; Silver City, 474 and 755; Clifton, 469 and 913; and Saint Johns, 437 and 672. The southern portion of the report area lies within the Mexican Highlands section of the Basin and Range province and the northern portion within the Colorado Plateau province. Uranium occurrences have been reported in the base-metal veins that occur in the Precambrian rocks; those in the Black Hawk, White Signal, and Burro Mountains districts are the most notable. Near the north end of the report area, uranium has been produced from the Baca and uppermost Mesaverde formations. Examination of the uranium data for both waters and sediments shows that there are uranium concentrations significant in both magnitude and areal extent in the Silver City and Saint Johns quadrangles. In the Silver City quadrangle, the notably high uranium concentrations in water and sediment are associated with the Precambrian outcrops in the Burro Mountains and adjacent Tertiary sedimentary areas. Over 20 water samples from wells in the southern part of the New Mexico portion of the Saint Johns quadrangle exhibit uranium concentrations in excess of 20 ppb. These wells penetrate the basal, sedimentary section of the Datil formation and the underlying Baca and uppermost Mesaverde formations. The portions of the Douglas and Clifton quadrangles for which data are reported have only a few isolated locations providing water samples with notably high values of uranium relative to the local mean. In the eastern half of the Clifton quadrangle, relatively high concentrations of uranium in sediment appear associated with rhyolitic rocks exposed in the vicinity of Granite Peak. (PAG)

The following appendices are included in the report: Appendix A - Standard Field and Analytical Procedures; Appendix B - Field and Uranium Data for the Water Samples; Appendix C - Field and Uranium Data for the Sediment Samples; Appendix D - Keys to the Water and Sediment Sample Types and Codes to Site Data.

258
Short, N.M.; NASA, Goddard Space Flight Center, Greenbelt, MD

Mineral Resources, Geological Structures, and Landform Surveys. NASA-SP-356; Third Earth Resource Technology Satellite, Proceeding of a Symposium, Washington, DC, December 10-14, 1973. National Aeronautics and Space Administration, Washington, DC, Vol. 2, Summary of Results, (pp. 147-167), 179 pp.(1974, May)

The use of ERTS data in map making, landform analysis, structural geology, lithologic identification, mineral exploration, and engineering and environmental geology was evaluated. ERTS permits more detail in the mapping of facies and formational subunits in certain areas than was previously attained by conventional methods. Basalts and granites are recognized in ERTS imagery and select formations are enhanced utilizing a technique of ratioing bands and reproducing images from the ratio signals. Because many known ore deposits are located close to NE and NW linears, ERTS imagery provides better definition of known linears and a much higher density of fractures than other methods. Surface alteration products can be detected using band ratios and color composites, and surface alteration enhancement with linear analysis. ERTS imagery has also proven useful in the recognition of potential geologic hazards. (PAG)

Cited as a reference in NURE contractor reports.

259
Skvarla, J.E.; Union Carbide Corporation, New York, NY

Improvements in and Relating to the Location of Uranium Ore Deposits and Apparatus Therefor. Patent 987,462; 6 pp.(1965)

The method for the location of uranium deposits comprises drilling a hole into the substrata region; sealing off a portion; evacuating gas present in the substrata region surrounding the sealed off portion through a radon absorbing means; and measuring the quantity of radon absorbed by adsorbent radiometric means to provide a measure of the amount of uranium producing the radon. This invention provides a method for uranium exploration, which may avoid the limitation of the emanation method, by spacing drill holes up to half a mile apart and which can be employed in both vertical and horizontal prospecting methods. This method further provides an apparatus for uranium exploration which may be transported in truck or carried by one man. (PAG)

Complete specification drawings are included in the patent report.

260
Smith, A.Y., A. Armour-Brown, H. Olsen, B. Lundberg, and P.L. Niesen; Nuclear Research Centre "Demokritos", Uranium Exploration Department, Aghia Paraskevi, Attikis, Greece

The Role of Geochemical Prospecting in Phased Uranium Exploration - A Case History. CONF-760316; IAEA-SM-208/51; Exploration of Uranium Ore Deposits, Proceedings of a Symposium, Vienna, March 29-April 2, 1976. International Atomic Energy Agency, Vienna, (pp. 575-599), 807 pp.(1976)

The paper reviews the exploration task, the strategy selected, and some results obtained. The project area (22,000 sq. kilometers) was explored by car-borne survey, covering 15,000 km of road and track. Concurrently a stream sediment geochemical survey was begun which aimed at a nominal sample density of one sample per square kilometer. Samples were analyzed for copper, lead, zinc, silver, cobalt, nickel, molybdenum, mercury and manganese, in addition to uranium. At each site, a general reading of radioactivity was made, and treated like another element analysis. The reconnaissance program succeeded in delineating a number of important target area, varying in size from a few to several hundred square kilometers with significant uranium potential. Follow-up and detailed surveys have been carried out over a number of these, including a sedimentary basin of continental deposits which have been found to contain occurrences of secondary uranium minerals, and two areas in which granitic bodies have been found to have fracture systems and secondary uranium mineralization of economic interest. In no case has sufficient work been done yet to prove economic deposits of uranium. The phased strategy used has, however, already been demonstrated to be effective in the environment of northern Greece. (Auth)

261
Smith, A.Y., P.M.C. Barretto, and S. Pournis; UNDP/IAEA Uranium Exploration Project, Greece; International Atomic Energy Agency, Vienna, Austria

Radon Methods in Uranium Exploration. CONF-760316; IAEA-SM-208/52; Exploration of Uranium Ore Deposits, Proceedings of a Symposium, Vienna, March 29-April 2, 1976. International Atomic Energy Agency, Vienna, (pp. 185-211), 807 pp.(1976)

Radon 222, the sixth member in the decay series of Uranium 238, and an inert gas, has a number of properties which make it an interesting and useful

pathfinder in locating uranium mineralization. The detection Radon 222 by the alpha particle produced in its decay to Polonium 218 provides the basis for an extremely sensitive analytical method. A number of instrumental and other techniques have been developed to perform this analysis. The advantages and disadvantages of some of the more common ones are reviewed. Various sample media may be utilized in radon surveys. These include lake and streamwater, ground-water and soil air or gas. Generally, it has been demonstrated that methods based on the detection of radon in water are reconnaissance methods and should be used only in the reconnaissance phase of uranium exploration. Methods based on the detection of radon in soil gas have been used in both the reconnaissance and detailed phases of uranium exploration, where they should be integrated into the exploration programme along with other geochemical and geophysical methods. A number of problems attend the collection and interpretation of data from radon surveys. Since these are, to a large extent, geochemical problems, sound knowledge of the geochemical dispension of radon and its precursors must be applied to the problem. The paper reviews the various phases in uranium exploration in which radon detection is applicable, discusses sample media and detection methods and offers some guidelines for using radon methods. (Auth)(MLB)

262
Smith, B., J.W. Cady, D.L. Campbell, J.J. Daniels, and V.J. Flanigan; USGS, Denver, CO

A Case for "Other" Geophysical Methods in Exploration for Uranium Deposits. CONF-760316; IAEA-SM-208/44; Exploration of Uranium Ore Deposits, Proceedings of a Symposium, Vienna, March 29-April 2, 1976. International Atomic Energy Agency, Vienna, (pp. 337-351), 807 pp.(1976)

Non-radiometric geophysical methods have important applications to uranium exploration problems. Gravity, magnetic, electromagnetic, and induced-polarization surveys, conducted on regional and local scales over a wide variety of uranium deposits yield meaningful data to aid in understanding the geochemical environments of uranium deposits and in mapping deposits. No one geophysical method can be expected to be universally successful in surveys over various uranium deposits, but with an understanding of the probable geochemical environment of an ore deposit, the selection of one or more geophysical methods can be made to significantly aid in exploration. The selection of geophysical methods will be enhanced as more geophysical work is done to identify parameters of the geochemical environment of uranium that may be detected by surface geophysical surveys. (Auth)(MLB)

263
Snider, J.L.; USGS, Washington, DC

Reconnaissance for Uranium in Coal and Shale in Southern West Virginia and Southwestern Virginia. TEI-409; 28 pp.(1953, July)

The reconnaissance for uranium in southern West Virginia and southwestern Virginia included field measurements of radioactivity of measured sections and the collection of thirty-three channel samples of coal, two shale samples, and twenty-eight samples of clay for laboratory determination of radioactivity. All samples of bituminous coal have less than 0.001 percent equivalent uranium. A sample of the Merrimac coal, a semianthracite coal of Mississippian age from Montgomery County, Virginia, may contain as much as 0.001 percent equivalent uranium. Samples of Upper Devonian shale contain 0.003 to 0.004 percent equivalent uranium. (Auth)(PAG)

264
Stahl, R.L.; US Bureau of Mines, Denver Mining Research Center, Denver, CO

Detection and Delineation of Faults by Surface Resistivity Measurements, Gas Hills Region, Fremont and Natrona Counties, Wyoming. US Bureau of Mines Report of Investigations 7824; 28 pp.(1973)

Comprehensive field tests were made in the Gas Hills, Wyoming, to determine whether surface geophysical techniques could be used to detect and delineate faults in marginal uranium deposits. The tests included seismic refraction, self-potential, induced polarization, magnetometer, electrical resistivity, airborne infrared thermal scanning, and airborne photography. Of the several geophysical techniques, horizontal resistivity profiling with electrode spacings in the range of 25 to 50 feet was most diagnostic of faults. (Auth)

265
Steenfelt, A., B.L. Neilsen, and K. Secher; Greenland Geological Survey, Copenhagen, Demark

Uranium Geology and Prospecting in Greenland. Geology, Mining and Extractive Processing of Uranium, Jones, M.J. (Ed.), Proceedings of a Symposium, London, January 17-19, 1977. Institute of Mining and Metallurgy, London, (pp. 8-12), 171 pp.(1977)

Anomalous radioactivity in west Greenland is recorded from carbonatite intrusions, and from units in Proterozoic and Archaean gneisses. No mineralization has been found to date. In south Greenland investigations have been centered on the uranium and thorium deposit at Kvanefjeld, which is situated in a corner of the Ilimaussaq alkaline intrusion. The coincidence of favorable conditions during the differentiation and crystallization of the magma led to an extreme enrichment of uranium and thorium in the rocks that were last formed - the lujavrites. The deposit comprises parts of the lujavrites and a secondary enrichment zone in the contact between lujavrite and basaltic cover rocks. Reasonably assured reserves are 5800 tons U with a grade of 310 ppm U. In the Caledonides of east Greenland some gneisses in basement cores, a dark siltstone in late Precambrian sediments and the Devonian acid magmatic rocks are characterized by a higher radiation level. A number of small mineral occurrences have been found, the majority of which are associated with the Devonian acid magmatic rocks. (Auth)(PAG)

266
Stewart, R.H.; USGS, Washington, DC

Radiometric Reconnaissance Examination in Southeastern Pennsylvania and Western New Jersey. TEM-255; 13 pp.(1951, December)

A torbernite deposit near Stockton, New Jersey, was examined and 350 miles of nearby roads, in southeastern Pennsylvania and western New Jersey, were traversed with a car-mounted Geiger counter. The torbernite deposit is estimated to contain 1,000 tons of rock averaging 0.009 percent uranium. The radioactivity of the area traversed by car was two to three times above normal, averaging 0.003 percent equivalent uranium. It is suggested that uranium deposits may be present in the Piedmont belt and flanking sedimentary rocks. (Auth)

267
Stow, M.H.; Washington and Lee University, Lexington, VA

Report of Radiometric Reconnaissance in Virginia, North Carolina, Eastern Tennessee, and Parts of South Carolina, Georgia, and Alabama. RME-3107; 33 pp.(1955, February)

Specific areas of known or suspected radioactivity in Virginia, North Carolina, two counties in NE Tennessee, and a few selected areas in South Carolina, Georgia, and Alabama were examined and samples collected and submitted for radiometric and chemical analyses. The degree of anomalous radioactivity ranged from 0.05 MR/HR, or only twice background, to over 20 MR/HR on veins of uraninite. Uniformly distributed, radioactivity was found in the basal Pennsylvanian sandstones of southwestern Virginia, in the basal Mississippian sandstones of central and southwestern Virginia, in the upper Devonian sandstones of western Virginia, and in the lower Cambrian Rome formation extending from central Virginia to central Alabama. Radioactivity of significant concentration was found in the Cranberry granite of Precambrian age in Avery and Burke counties, North Carolina. Chemical analyses of selected samples from this area have shown the presence of as much as 0.5 percent U3O8. Veins of uraninite have been located in this area. A relationship between faulting or shearing and concentration of radioactive mineralization is indicated. (PAG)

268
Strelow, F.W.E., M.L. Kokot, T.N. Van Der Walt, and B. Bhaga; National Chemical Research Laboratory, Council for Scientific and Industrial Research, Pretoria, Republic of South Africa; Minachem Limited, Johannesburg, Republic of South Africa

Rationalized Determination of Uranium in Rocks for Geochemical Prospecting Using Separation by Ion Exchange Chromatography and Spectrophotometry with Arsenazo III. The Journal of the South African Chemical Institute 24(2-3):97-104.(1976)

A method is presented for a rationalized and economical determination of small amounts of uranium in rocks. The method is suitable for geochemical prospecting. The uranium is leached from the rock by a sulphuric-nitric acid mixture, and the filtered solution is passed through a column containing BIO-RAD AGI-X8 anion

exchange resin in the sulphate form. Interfering elements are eluted selectively and the retained uranium is finally eluted with 80 ml of 0.1m-hydrochloric acid. The uranium is then determined by measuring the absorbance of its complex with arsenazo III in a citrate buffer of pH 2.5 at 650 nm. Thirty determinations per working day can be carried out by a single operator using a bank of 30 ion-exchange columns. The results compare favorably with those obtained by other methods. (Auth)

269
Tanner, A.B., R.M. Moxham, and F.E. Senftle; USGS, Reston, VA

Assay for Uranium and Determination of Disequilibrium by Means of In Situ High-Resolution Gamma-Ray Spectrometry. USGS Open-File Report 77-571; 22 pp.(1977, July)

For assay of uranium in deposits whose equilibrium has been disturbed by leaching within the preceding several months, a stepwise neutron-activation, delayed-gamma technique using a high-resolution detector optimized for low energies is suitable to a sensitivity of the order of 100 ppm U3O8 when a 4 x 10(E+8) n/s Cf252 source irradiates a station for 25 minutes and the resulting activity of U 239 is counted promptly for 2 minutes. The stepwise technique has the disadvantages of requiring a neutron source, of needing accurate positioning of the detector at the location previously irradiated, and of not permitting arbitrarily close spacing of data points on the same run. Continuous-motion neutron-activation, delayed-gamma logging is not feasible without very strong sources; that is, of the order of 10(E+10) n/s. For assay of uranium in deposits that have not been leached within the preceding several months, high-resolution gamma-ray spectrometry of the natural radioactivity of the deposit yields good sensitivity, free from the influences of disequilibrium, radon contamination, and thorium. A routine cycle of 10 minutes of measurement and 5 minutes of data reduction and movement to the next station should be practicable and should yield a sensitivity of about 80 ppm U3O8. The high-resolution sonde may operated in a total-count, continuous-motion mode to achieve the same results as conventional scintillation logging at comparable speeds. In comparison with core assay, high-resolution spectrometry samples a larger volume; avoids problems due to incomplete core recovery, loss of friable material to drilling fluids, and errors in depth and marking; and permits use of less expensive drilling methods. (MLB)

Numerous diagrams and graphs are included in this report.

270
Teichman, R.A., Jr., I.T. Fisk, and C.D. Thompson; AEC, Grand Junction Office, Grand Junction, CO

Exploration Drilling, Dry Valley District, San Juan County, Utah. TM-74; 6 pp.(1955, June)

Exploratory drilling to evaluate the potential and ore reserves in the Dry Valley district was conducted in the President Wilson, Waterfall, and Frisco groups of claims between August 25, 1953, and February 11, 1954. A total of 40,664 feet were drilled into the upper sandstone of the Salt Wash member of the Jurassic Morrison formation. Of the 183 holes drilled, 21 were ore holes, 41 mineralized holes and 121 were barren. The average grade of the ore is 0.34 percent U3O8, 1.83 percent V2O5, with an average thickness of 2.2 feet. Orebodies in these areas are small and tabular and of the carnotite-vanadium type. (Auth)

271
Truesdell, D., R. Wegrzyn, and M. Dixon; Bendix Field Engineering Corporation, Grand Junction Operations, Grand Junction, CO

Provenance of Radioactive Placers, Big Meadow Area, Valley and Boise Counties, Idaho. GJBX-15(77); 53 pp.(1977, February)

The largest of the radioactive black-sand placers in the Bear Valley area of west-central Idaho is in Big Meadow, near the head of Bear Valley Creek. Presence of these placers suggests that low-grade uranium deposits might occur in rocks of the Idaho Batholith. The principal radioactive minerals in these placers are monazite and euxenite. Other minerals include columbite, samarskite, fergusonite, xenotime, zircon, allanite, sphene, and brannerite. Only brannerite is a uranium mineral; the others contain uranium as an impurity in crystal lattices. All are probably accessory minerals in the plutonic rocks. Radiometric determinations of the concentration of uranium in stream sediments strongly indicate

that the radioactive materials originate in an area drained by Casner and Howard Creeks, which are eastern tributaries to Bear Valley Creek. Equivalent uranium levels in bedrock are highest on the divide between Casner and Howard Creeks, indicating that this is the probable source for the radioactive placers. Euxenite, brannerite, columbite-tantalite, samarskite, and allanite are the principal radioactive minerals identified in granite pegmatites, granites, and quartz monzonites. Appreciably higher equivalent uranium concentrations were also found within these rock types. (PAG)

272
Tugarinov, A.I., G.E. Ordynets, R.N. Sherbakova, and E.I. Krys'kov

Using Variations in the Isotope Composition of Lead in Survey Work on Uranium-Bearing Regions. Soviet Journal of Atomic Energy 25(1):1311-1316.(1968, July)

When the concentrations of uranium and thorium in rocks are so high that their minerals appear as almost pure ores, radiogenic lead must accumulate, and possibly migrate. In the latter case, a halo of lead with abnormal isotope composition must develop around uranium deposits. The Pb 206 and Pb 207 concentration in lead must increase with decreasing distance from the uranium deposit. Isotopic analyses of lead can help to exclude "spurious" ore anomalies which are observed with other geochemical methods, but have no relation to the actual ore-forming processes. Lead with a clearly abnormal isotope composition can serve as an indicator in uranium prospecting in the hypergenesis zone, in which other indicators pointing to uranium mineralization are not present. The Pb 206/Pb 208 ratio in the total lead of a mineral can be used as direct indicator in uranium prospecting, however, it must be considered that a rare, yet possible, contamination of the mineral by an excess of lead originating from thorium. This reduces the usefulness of the ratio. (JMT)

273
Vine, J.D., and G.W. Moore; USGS, Washington, DC

Reconnaissance for Uranium-Bearing Carbonaceous Rocks in Northwestern Colorado, Southwestern Wyoming, and Adjacent Parts of Utah and Idaho. TEI-281; 25 pp.(1952, October)

During the reconnaissance for uranium-bearing coal in parts of Colorado, Wyoming, Utah, and Idaho, the most significant deposit found was in the Fall Creek area, Idaho. In addition, three localities were found in which coal beds contain more than 0.010 percent uranium in the ash. They are located near Lay, Colorado; Walden, Colorado; and the Leucite Hills, Wyoming. Coal beds north of Sage, Wyoming, contain 0.008 percent uranium in the ash; gilsonite south of Rand, Colorado, contains 0.016 percent uranium in the ash; and bitumen west of Vernal, Utah, contains 0.028 percent uranium in the ash. Approximately 350 samples of coal, carbonaceous shale, asphaltite, and related carbonaceous materials were collected for uranium analysis. In addition, 20 samples of spring water from potential source beds and from mineral springs were submitted for uranium determination. Approximately 30 rock samples of tuffaceous sandstones and volcanic rocks were also collected for uranium analysis. Special attention was given to carbonaceous rocks associated with or overlain by tuffaceous sandstone and volcanic tuff. (MLB)

274
Wedow, H., Jr., and P.L. Killeen; USGS, Washington, DC

Reconnaissance for Radioactive Deposits in Eastern Interior Alaska, 1946. USGS Circular 331; 36 pp.(1954)

A reconnaissance of areas adjacent to highways in the Tanana and upper Copper River Valleys was conducted in 1946. The objectives of the reconnaissance were to determine whether significantly radioactive veins occurred in the vicinity of the placers from which radioactive concentrates had been obtained and to conduct a routine survey for radioactive deposits in accessible areas adjacent to highways in eastern interior Alaska. The reconnaissance did not yield any further information concerning the source of the few radioactive placer concentrates, but a few new sites of radioactivity were found. Vein deposits, consisting primarily of quartz veins containing gold and metallic sulfides, contained up to 0.005 percent equivalent uranium. Graphitic schists and black shales in the area contained a maximum of 0.004 percent equivalent uranium. Tests of granitic and mafic igneous rocks indicate maxima of 0.006 percent and 0.005 percent equivalent uranium, respectively. Concentrates from placer deposits locally contained as much as 0.066 percent equivalent uranium. (JMT)

275
Wenrick-Verbeek, K.J., R.A. Cadigan, J.K. Felmlee, G.M. Reimer, and C.S. Spirakis; USGS, Denver, CO

Recent Developments and Evaluation of Selected Geochemical Techniques Applied to Uranium Exploration. CONF-760316; IAEA-SM-208/18; Exploration of Uranium Ore Deposits, Proceedings of a Symposium, Vienna, March 29-April 2, 1976. International Atomic Energy Agency, Vienna. (pp. 267-281), 807 pp.(1976)

The study of radioactive springs has suggested the following tentative conclusions: (1) radium in spring waters is considered an indicator of deep uranium deposits; (2) the occurrence of radium and uranium in mineral springs and spring deposits is to a large extent independent of the geochemistry of the solutions and of the accumulated precipitates; and (3) radioisotopes in spring precipitates are indicative of the composition of the radioactive source rocks and the present rate of movement of the radioactive constituents. The following procedure should be followed for the sampling of surface water and associated sediment for uranium exploration: (1) sampling should be done during times of minimum stream discharge; (2) conductivity should be measured in situ; (3) turbid samples should be filtered immediately in situ; (4) only the stream-sediment fraction less than 90 micrometer (170 mesh) should be analyzed for uranium; and (5) both water and stream sediments should be analyzed from each site and if the water is at all turbid the suspended fraction should be preserved and analyzed separately. A sample collection procedure has been designed to utilize the advantages of the fission-track technique in water sampling. These advantages are: (1) only a small drop of water is required, typically 25 microliter; (2) sample manipulation is minimized, as only one contact with the sample is required; (3) sample integrity is maintained during transport and storage, so that no uranium loss or gain considerations are involved; and, (4) a qualitative determination can be made as to whether the uranium is in solution or in the suspended material. The use of standards and comparison of the fission-track technique to others using larger quantities of samples shows good correlation of data, considering the representativeness of the sample size. Computer-enhanced Landsat (ERTS) data may be used to define altered areas around uranium deposits. "Enhanced natural color" images are useful for defining lithologic and formation boundaries, and stretched-ratioed images may be used to enhance altered zones. In areas of broad exposures of rocks with little vegetation cover and sharp color contrast between the altered zones and the non-altered rocks, this technique is ideal as an early step in the reconnaissance of a large area. (MLB)

276
West, W.S.; USGS, Washington, DC

Reconnaissance for Radioactive Deposits in the Lower Yukon-Kuskokwin Region, Alaska. USGS Circular 328; 10 pp.(1954)

Reconnaissance in the lower Yukon-Kuskokwin region during 1952 consisted of an examination for radioactivity of a metazeunerite occurrence in the Russian Mountains and molybdenite occurrences in the Marshall area and in the southern Kaiyuh Mountains. Metazeunerite, a hydrous copper-uranium arsenate, was identified in a concentrate of arsenic copper vein material found on the Konechney prospect in the Russian Mountains. No other occurrences of uranium minerals have been found. The oxidizing and highly acid environment of the ore dumps and bedrock outcrops in the Russian Mountains could account for the scarcity of secondary uranium minerals and the absence of primary uranium minerals near the surface. If this is the case, the trace amounts of metazeunerite that have been found may indicate that larger amounts of secondary uranium minerals occur at greater depths and possibly grade downward into significant deposits of primary uranium minerals. No uranium deposits of commercial importance were found in the Marshall and southern Kaiyuh Mountains area. (JMT)

277
Woolson, W.A., and M.L. Gritzner; Science Applications, Incorporated, La Jolla, CA

Borehole Model Calculations for Direct Uranium Measurement with Neutrons. GJBX-44(77); SAI-77-506-LJ; 114 pp.(1977, January)

Three neutron logging tools were investigated for use in uranium exploration. One tool utilizes the pulsed 14 MeV source to detect the Prompt Fission Neutrons (PFN) return, the second utilizes a pulsed 14 MeV source to detect Delayed Fission Neutrons (DFN), and the third employs a Cf 252 source to detect uranium from the DFN signal. This model permits the analysis of the sensitivity

of tool performance to variations in design parameters, and borehole and rock matrix configurations. Conclusions reached on the three tool designs are: 1) One tool has no significant advantage over the others in terms of the potential signal that can be detected; 2) Variations in borehole diameter and rock moisture have a greater influence on the transport of the PFN and DFN signal return than on the transport of source neutrons into the rock, with the greatest variation occurring for the Cf 252/DFN tool; 3) There is less variation in the count as a function of borehole diameter and rock moisture for the DFN tools than the PFN tool-the 14 MeV/DFN tool is the easiest to calibrate for these variations; 4) The Cf 252/DFN tool is more sensitive to ore variations close to the borehole than the 14 MeV tools, while the 14 MeV tools will produce larger signals for ore deposits relatively far from the borehole; and 5) The amount of borehole fluid affects the origin of the Delayed Oxygen Neutrons (DON) return for the 14 MeV sources, thus adversely affecting the DON calibration method of the 14 MeV/DFN tool for large mud-filled boreholes and the N 16 source monitor technique for dry or small boreholes. (PAG)

278
Wormald, M.R., and C.G. Clayton; Nuclear Physics Division, Harwell, Didcot, Oxon, United Kingdom

Some Factors Affecting Accuracy in the Direct Determination of Uranium by Delayed Neutron Borehole Logging. CONF-760316; IAEA-SM-208/35; Exploration of Uranium Ore Deposits, Proceedings of a Symposium, Vienna, March 29-April 2, 1976. International Atomic Energy Agency, Vienna, (pp. 427-470), 807 pp.(1976)

The absolute detector response in the delayed neutron method of borehole logging for uranium has been derived by Monte Carlo calculations based on a realistic model. The operational characteristics of the method have been investigated and it has been shown that, to achieve the highest sensitivity, Cf 252 is preferred to a 14-MeV neutron source. Mechanical pulsing of the source coupled with time-sequencing in the detector is recommended. The influence of several characteristics of the rock formation on the accuracy of the measurement has been studied. The most important feature of the formation has been shown to be the occurrence of elements which dramatically increase the macroscopic absorption cross-section of the formation. A separate measurement of this parameter may be required. Iron is one of the elements which can strongly affect the measurement. Although variations in rock density and moisture content influence detector response it is probably not necessary to take separate account of these variations. Detection limits to within a few tenths of ppm uranium concentration appear practicable. (MLB)

279
Wright, R.F.; AEC, Grand Junction Office, Geologic Branch, Grand Junction, CO

Application of the Dithizone Heavy-Metals Test to Uranium Deposits of the Chinle Formation Near Cameron, Arizona. TM-92; 8 pp.(1957)

Dithizone test indicate that uranium-bearing altered sandy mudstone lenses in the Petrified Forest member of the Chinle formation commonly have a high content of zinc, copper, and lead. The greatest concentration of heavy metals is usually in the lower 25 feet of the deposits, and in some areas may reach several thousand ppm in the lower parts, increasing toward the most depressed area of the saucer shaped deposits. The heavy metal content in unmineralized or unaltered Chinle is usually less than 150 ppm. Anomalous amounts of heavy metals found in fresh unweathered cutcrop samples probably indicate that uranium is present and that more detailed sampling or exploration should be done. (Auth)(MLB)

Tables and figures are included in this report.

280
Zeigler, R.K., D.V. Susco, G. Wecksung, K. Campbell, and T.R. Bement; Los Alamos Scientific Laboratory, Los Alamos, NM

Geostatistics Project of the National Uranium Resource Evaluation Program. LA-6935-PR; 14 pp.(1977, April)

Data collected by Geodata International, Incorporated, on the air reconnaissance of the 1 degree by 2 degrees Lubbock Quadrangle were analyzed. Spline smoothing followed by subsampling of records was done in an investigation of the feasibility of reducing the data set to a more manageable size. A computerized method of contouring irregularly

spaced points has been implemented and used on the Lubbock data set. The reduced data set was also used to prepare gray-level and pseudocolor maps of the potassium, bismuth, and thallium signals in the Lubbock Quadrangle. (Auth)(MLB)

281
Zeigler, R.K., D.E. Whiteman, M.S. Waterman, and T.R. Bement; Los Alamos Scientific Laboratory, Los Alamos, NM

Some Problems Associated with the Analysis of National Uranium Resource Evaluation (NURE) Data. LA-6758-C; Second ERDA Statistical Symposium, Proceedings of a Symposium, Oak Ridge, TN, October 25-27, 1976. Los Alamos Scientific Laboratory, Los Alamos, NM, (pp. 212-238), 276 pp.(1977, April)

One aspect of the National Uranium Resoure Evaluation (NURE) Project involves the evaluation of large quantities of data resulting from an airborne survey of regions in the continental United States and Alaska. Observations in the form of gamma ray signals are taken approximately every 176 feet on transects which are approximately six miles apart. The objective is to classify regions with respect to their potential mineralization. The quantity of data has created problems relative to its graphical representation as well as its analytical treatment. Geologists feel that the probability distributions of certain random variables, such as Bi 214 signals over a given geological formation on a transect, may be related to uranium concentration. Progress has been made in an effort to draw conclusions from a large number of empirical distributions representing a wide geographical region. A technique for computing empirical density functions has been developed and as many as 100 of these densities (each representing a transect) have been displayed simultaneously through the use of three-dimensional and gray-level computer generated plots. Such displays allow one to view not only general trends over large regions, but to examine details on any given transect. One important aspect of the analysis of this data deals with the problem of defining and locating anomalous regions in a set of sequential data taken along a transect. Methods involving the location of those segments in a sequence which have maximum total variance and Andrew's (1972) sin function M-estimate of a location parameter have been used. These methods are compared to the technique of simply computing a mean and a standard deviation and labeling regions anomalous if they deviate from the mean by more than two or three standard deviations. (Auth)(MLB)

282
Zeller, E.J., G. Dreschhoff, K. Holdoway, and D.F. Saunders; University of Kansas, Geology Department, Lawrence, KS

Use of Gamma-Ray Logs from Wells Drilled for Petroleum Exploration to Define Uranium Provinces in Subsurface Formations. CONF-760316; IAEA-SM-208/41; Exploration of Uranium Ore Deposits, Proceedings of a Symposium, Vienna, March 29-April 2, 1976. International Atomic Energy Agency, Vienna, (pp. 415-425), 807 pp.(1976)

The western portion of Kansas has provided a test area for the development of a new method of outlining potential uraniferous provinces in the subsurface. The gamma-ray logs from oil or gas wells or exploratory holes have been subjected to trend surface analysis, computer contouring, and statistical evaluation outlining areas of anomalously high gamma-ray activity in the Dakota and Morrison formations. The most prominent of these are located in central western Kansas where they correlate quite well with areas of high uranium content in the shallow ground-waters. No ore-grade readings were obtained, but some groups of wells showed high readings as great as 50 ppm eU. Examination of the maps showed that in some cases vertical stacking of anomalies in the Morrison and the Dakota occurs and in others it does not. Examination of other well logs throughout the remainder of the study area has identified other potentially favorable beds and general geographical areas which may contain deposits. It is concluded that gamma-ray logs from wells drilled for petroleum exploration are valuable aids in delimiting uraniferous provinces in subsurface formations. Since this type of information is gathered on a routine basis in many parts of the world, it appears that it should serve as a valuable new technique for uranium evaluation in these areas. In attempting to link the uraniferous provinces with geological factors which might influence their distribution, several possible correlations were discovered. It was found that the anomalies located by this technique are related to lineaments visible on the surface in earth satellite imagery. The spatial association of lineaments with uranium deposits is thought to be caused by

the lineaments acting as vertical transmission paths for mineralizing ground-water. The ground-water in the western portion of the study area is known to contain anomalously high values of uranium, and downward percolation of this water into formations where conditions of chemical reduction occur could result in some of the observed anomalies. The area of anomalous well log readings is underlain by thick beds of salt which is sufficiently plastic that fractures cannot remain open. Since the salt has not dissolved, it is clear that any uranium which is present must either be penecontemporaneous or from downward migration of uranium-bearing solutions. An examination of the anomaly maps shows that the largest contiguous anomalies are located over one of the main salt bodies and are approximately coincident with its margins. This suggests that the salt acted as a barrier to downward percolating waters, and its presence may be an important factor in the genesis of any uranium concentrations which may be present. (MLB)

283
Zelier, H.D.; USGS, Washington, DC

Reconnaissance for Uranium-Bearing Carbonaceous Materials in Southern Utah. USGS Circular 349; 9 pp.(1955)

A reconnaissance investigation for uranium-bearing carbonaceous materials was made in three major areas of southern Utah: Kaiparowits Plateau, Henry Mountains, and Kolob Terrace. No uranium deposits of economic interest were found. A few 1- to 2-foot beds of carbonaceous shale in the Dakota Sandstone contained 0.006-0.007 percent uranium. Other carbonaceous sediments that were examined contained 0.002 percent or less uranium. (Auth)

GEOLOGY OF DEPOSITS

284
AEC, Grand Junction Operations Office, Production Evaluation Division, Grand Junction, CO

Guidebook to Uranium Deposits of Western United States. RME-141; 359 pp.(1959, October)

This guidebook was prepared as an aid to a three month training program by the AEC. The geologic setting of a wide variety of deposits in the Plateau Area, Grants Area, Colorado Mountain Area, Casper Area, and the Salt Lake Area is presented. Bedded sandstone deposits are emphasized in the Colorado Plateau and in Wyoming; other types of deposits studied are those in sandstone in a near collapse structure; deposits in fresh-water limestone and in ancient karst structures in marine limestone; deposits in lignitic hosts; deposits at or near intrusive contacts; and vein deposits. A selected bibliography of uranium geology, exploration, and mining is also included. (PAG)

285
Akright, R.L.; AEC, Grand Junction Office, Grand Junction, CO

Geology and Uranium Deposits of Calf Mesa, Emery County, Utah. TM-101; 13 pp.(1957, February 4)

Uranium ore on Calf Mesa is in the Moss Back member of the Chinle Formation, which forms a gently northerly dipping cuesta in the northwest part of the San Rafael Swell, a breached asymmetrical elliptical dome. Three units of the Moss Back Member of the Chinle Formation are distinguishable; a lower sandstone unit; a middle mudstone, mudstone gall, and lime pebble conglomerate unit; and an upper sandstone unit. A fourth unit beneath these three composed of mudstone and lime pebble conglomerates may be correlative with the Monitor Butte Member of the Chinle. Sporadic and inconsistent mineralization is associated with carbonaceous debris and asphalt. Localization of ore in the low of a scour in one area is the only certain ore control in the lower sandstone unit. The absence of red mudstone seems to be a local guide to mineralization. The mineralization appears to have occurred before faulting of the area. During the exploration drilling program two ore holes were located in the northeastern part of Calt Mesa. Development drilling operations were performed in this area to determine whether or not the area contained a mineable ore body. Twenty air rotary holes were drilled for a total footage of 2,660 feet, but no significant amount of ore was located. (Auth)(PAG)

286
Alekseyev, F.A., R.P. Gottikh, V.Ya. Vorob'yeva, and L.V. Murav'yeva; All-Union Nuclear Geophysics and Geochemistry Research Institute, Moscow, USSR

Uranium Distribution in Sedimentary Rocks in the Western Part of the Amu Darya Petroleum Basin. Geochemistry International 6(5):963-970.(1969)

The distribution of some Mesozoic sedimentary rocks of West Uzbekistan was studied and found to be related to conditions of sedimentation and diagenesis. The uranium distribution in the depositional basin shows a clear zoning reflecting various sedimentary environments. The high uranium concentrations were related to shallow coastal facies, with the uranium content decreasing in the transition zone and increasing again towards the open sea. The distribution according to rock type varies with the facies zone. The maximum contents occur in sandstones in coastal shallow-water facies, whereas the usual tendency is for uranium contents to increase from sandstones through siltstones to clays in the open sea facies. The amount and type of organic matter in the sediments in critical to the distribution of uranium. Fission track analysis showed that the uranium was associated with clumps of organic matter. (JMT)

287
Alia, M.

Relaciones Entre Mineralizaciones Uraniferas en Expana y la Evolucion Morfologica. International Geological Congress, Proceedings of a Conference, Copenhagen, Denmark, 1960. Part 15, Genetic Problems of Uranium and Thorium Deposits, (pp. 67-72), 164 pp.(1960)

Many radioactive deposits in Spain are located on the surface of erosional platforms which are generally Pliocene in age. Some of these deposits

represent the upper alteration zones of primary deposits, others are merely surface concentrations of uranium that has been leached from rocks of surrounding areas. These secondary deposits were formed at a time when the ground water level was higher than now and when, because of climatic conditions, evaporation was high and caused surface concentration of uranium. Deep entrenchment of the drainage system during Quaternary time lowered the ground water level and thereby these secondary deposits became perched. Subsequent weathering and erosion destroyed the deposits partially. During the same time, however, new deposits were formed on lower levels. Primary uranium deposits generally contain a partially or almost totally leached zone which came into existence by lateral leaching corresponding with lowering of ground water levels. (Auth)

288
Baumgardner, L., and E.A. Noble; AEC, Grand Junction Office, Grand Junction, CO

Investigation of the Calyx No. 3 Mine, Temple Mountain Area, San Rafael Swell, Emery County, Utah. TM-75; 12 pp.(1957, April 10)

The uranium ore is in a cross-bedded sandstone in the lower part of the fluviatile Moss Back Member of the Triassic Chinle Formation. Uranium and vanadium are contained in asphaltic hydrocarbons which impregnate the ore sandstone. Paleochannel control of the ore in the Calyx No. 3 mine is not obvious, but a comparable control is present in the form of a permeable sandstone unit overlain and underlain by units of lower permeability. (Auth)

289
Becraft, G.E., D.M. Pinckney, and S. Rosenblum; USGS, Washington, DC

Geology and Mineral Deposits of the Jefferson City Quadrangle, Jefferson and Lewis and Clark Counties, Montana. USGS Professional Paper 428; 101 pp.(1963)

The Jefferson City quadrangle was mapped as part of a general study of the geology and mineral deposits in and around the Boulder Batholith. Ore deposits in the quadrangle have been valuable chiefly for silver and lead, and to a lesser extent, for gold, zinc and copper. Mining was most active before 1900. A few small uranium deposits have been discovered in the area, but little uranium ore has been shipped. The mineral deposits are almost entirely in veins along sheared or brecciated zones. Two distinctly different types of veins are distinguishable: (1) coarsely crystalline quartz and (2) chalcedony and microcrystalline quartz. Most of the base and precious metals occur as sulfide ore bodies in quartz veins. The chalcedony veins are almost barren of sulfide minerals, but they do contain most of the small uranium deposits that have been found. (JMT)

290
Billings, M.P., and N.B. Keevil; Harvard University, Cambridge, MA; University of Toronto, Toronto, Canada

Petrography and Radioactivity of Four Paleozoic Magma Series in New Hampshire. Bulletin of the Geological Society of America 57:797-828.(1946, September)

The Ordovician, Silurian, and Devonian strata of New Hampshire are intruded by igneous rocks belonging to four magma series, the oldest of which is late Ordovician, the youngest of which is Mississippian. Each magma series consists of rocks ranging from gabbro, diorite, or quartz diorite to granite. Although individual specimens from a rock type within a single magma series commonly show considerable range in radioactivity, the average values show a progressive increase in radioactivity toward the granitic end of the series, which is three to four times as radioactive as the gabbro-diorite end of the series. The reason for this increase toward the granitic end of the series is not always clear, but in the White Mountain magma series this appears to be due to an increase in the amount of allanite and probably zircon. This magma series is twice as radioactive as the other magma series and considerably more radioactive than similar rocks elsewhere in North America. It is suggested that the parental basaltic magma from which the White Mountain magma series was differentiated was more radioactive than the primary magmas from which the older magma series were derived. (Auth)

291
Bowes, W.A., W.E. Bales, and G.M. Haselton; AEC, Division of Raw Materials, Salt Lake City, UT

Geology of the Uraniferous Bog Deposit at Pettit Ranch, Kern County, California. RME-2063, Part 1; 29 pp.(1957, October)

Uranium associated with peat humus was discovered in a boggy meadow in Kern County California. The ore is an organic soil composed of growing grasses, mosses, and bog plants as well as peat mixed with detrital silt and sand derived from the underlying Jurassic quartz diorite. The uranium is confined to the organic material and probably exists as a metallo-organic complex. No uranium minerals have been identified. The Pettit Ranch uranium deposit is not a fossil but is an ore body in the making. Uranium has been and is being deposited by uraniferous spring waters emerging from an active fault. The spring waters contain an average of 0.11 ppm uranium, over 10 times that of local drainage waters. Laboratory tests show that the ore is not amenable to present metallurgical processes. Preliminary roasting is necessary to obtain high extraction of the uranium. Tests indicate that the ore may be upgraded over 100 percent by first separating the detrital minerals from the organic matter, then roasting the organic fraction to ash. Roasting alone serves to upgrade the raw ore 25 percent. Primary ore controls at the Pettit Ranch deposit are: (1) waters of high uranium content, (2) a suitable collector for the uranium (peat), and (3) restricted circulation. (MLB)

292

Boyd, F.S., Jr., and C.P. Bromley; AEC, Grand Junction Office, Grand Junction, CO

Reconnaissance of the Aspen Area, Including the Smuggler Mine, Pitkin County, Colorado. RME-4031; 23 pp.(1953)

A radiometric reconnaissance of sediments, igneous rocks, and mines in the Aspen area revealed no significant radioactivity except in the Smuggler mine. Uranium in the mine occurs in a fault breccia composed of dolomitic limestone blocks and fragments in a carbonaceous shale matrix. The uranium is found in the matrix; associated with it are variable amounts of lead and zinc sulfides and silver sulfides and sulfo-salts. The major uranium mineral is believed to be primary pitchblende, but positive identification was not made. Some uranium is also found in secondary barite that contains free silver and in association with incrustations of goslarite (a hydrous zinc sulfite). (MLB)

293

Byrant, B., and J.C. Reed, Jr.; USGS, Washington, DC

Mineral Resources of the Grandfather Mountain Window and Vicinity North Carolina. USGS Circular 521; 13 pp.(1966)

The mineral resources of the Grandfather Mountain Window area of North Carolina are discussed in this report. The most valuable and largest mineral resources in the area presently known are gravel, sand, road metal, and building stone. Uranium, lead, zinc, manganese, gold and copper also occur in small amounts. There was considerable prospecting for uranium in the Grandfather Mountain area in the middle 1950's, but no minable deposits were found. The areas of greatest activity were in the Wilson Creek Gneiss and the Cranberry Gneiss. Radioactive minerals were prospected in: 1) heavy mineral partings rich in zircon in the clastic rocks of the Chilhowee Group and in arkoses of the Grandfather Mountain group; 2) small pegmatites in the Cranberry Gneiss; and 3) strongly sheared and phyllonitic zones in the Wilson Creek Gneiss. The most promising of the three occurrences is that in the Wilson Creek Gneiss. The most abundant uranium minerals occur in scattered uraninite-filled joints in sheared pegmatites in phyllonite zones. (JMT)

294

Callaghan, E.; Utah Geological and Mineralogical Survey, Salt Lake City, UT; University of Utah, College of Mines and Mineral Industries, Salt Lake City, UT

Mineral Resource Potential of Piute County, Utah and Adjoining Area. Bulletin 102; 135 pp.(1973, June)

The Marysvale region includes Piute County with adjoining parts of Beaver, Sevier, and Garfield counties. Gold, silver, quicksilver, copper, lead, zinc, uranium, manganese, iron, alunite for potash, alunite for aluminum, sulfur, and blending clay for brickmaking have been produced and fluorspar and corundum have been prospected in this area. The known vein type uranium deposits in the Henry Mining District and the Newton Mining District have been mined out. No disseminated copper minerals were noted in spite of widespread alteration and numerous quartz monzonite intrusions. Large reserves of alunite

deposits remain but quicksilver, manganese, iron, lead and zinc occur in small uneconomic deposits. (PAG)

295
Campbell, D.L., and R.I. Grauch; USGS, Denver, CO

Ground Magnetic, E-Mode VLF, and Radiometric Surveys at Phillips Mine-Camp Smith Uranium Prospect, Westchester and Putnam Counties, New York. USGS Open-File Report 77-780; 18 pp.(1977)

Precambrian uraninite in the Phillips Mine-Camp Smith area, New York, appears to be localized along the boundary between light-colored hornblende leucogneiss and dark-colored amphibole gneiss units. It is associated with magnetite-rich and scapolite-rich layers, with hornblende pegmatites, and with the outer shell of a massive sulfide body. The close spatial association of uraninite, magnetite, and sulfides result in nearly-coincident geophysical anomalies involving high eU channel, high total magnetic field, and low VLF apparent-resistivity measurements. (Auth)

296
Chamberlain, V.R., and J.W. Hill; Union Mines Development Corporation, Grand Junction Field Office, Grand Junction, CO

Report on Comb Ridge Fold District, San Juan Basin Area, Utah. RMO-448; 50 pp.(1946, March)

The Salt Wash Sandstone, the ore-bearing member of the Morrison formation, is in places, well exposed and dissected by numerous steep-walled canyons. Known ore occurrences are scattered, lenticular, thin, and generally low grade. Many are merely pods of ore only a few feet long. It is suggested that these deposits are the fringe sediments of now eroded ore bodies. Extensive but low grade mineralization occurs in all claim groups but those with more important areas of mineralization are the Main Montezuma Canyon group, Coal Bed Canyon group, Upper Monument Canyon group, and the Bradford Canyon group. Indicated ore tonnage is 11,250 with 5,250 of Grade 1, 5,300 of Grade 2, and 500 of Grade 3. Ore tonnage of Grade 3 or better is also estimated at 400,000 tons of "inferred" ore. (PAG)

297
Cupp, G.M., S.H. Leedom, T.P. Mitchell, and D.R. Allen; Bendix Field Engineering Corporation, Grand Junction Operations, Grand Junction, CO

Geology, Uranium Deposits, and Uranium Favorability of the Hartford Hill Rhyolite and Truckee Formation, Southwestern Washoe County, Nevada, and Eastern Lassen County, California. GJBX-16(77); 61 pp.(1977, February)

The Hartford Hill Rhyolite is a series of ash-flow sheets that range in age from late Oligocene to early Miocene. This series attains a maximum stratigraphic thickness of approximately 4,000 feet. The formation is divided into seven ash-flow tuff cooling units and avalanche deposits, which range in composition from rhyolite to andesite. The Truckee Formation is a sequence of alternating lacustrine, fluvatile, and volcanic rocks of Pliocene age, which attains a thickness in excess of 3,000 feet. Basaltic and rhyolitic lava flows are found at or near the base of the formation. Above these flows are sandstones and conglomerates that grade upward to clayey lake beds and tuffs. In Long Valley the upper one-third of the formation is a quartzitic sandstone. Mudflow sheets with large granitic boulders are scattered throughout the sequence. All known uranium deposits in the Hartford Hill Rhyolite, with one exception, are confined to two cooling units. The deposits are localized by organic material, fractures, and dikes. They are small deposits that range in grade from less than 100 ppm to 800 ppm U_3O_8. Uranium deposits in the Truckee Formation are near the base of the formation, adjacent to contacts with the underlying Hartford Hill Rhyolite. Deposits have been localized by organic material, by thin clay beds, or along contacts with the Hartford Hill Rhyolite. These deposits are small in size and range in grade from less than 100 ppm to 410 ppm U_3O_8. No genetic relationship was observed between Tertiary intrusive rocks and uranium occurrences. Favorability for important uranium deposits in the Hartford Hill Rhyolite is judged to be low. The known occurrences are of limited extent, and the overall uranium content of the formation is low (4 to 10 ppm U_3O_8). However, because of the thickness and extent of the formation and the uranium occurrences contained in it, it may have been a source for uranium in the younger, topographically lower Truckee Formation. Uranium favorability of the Truckee Formation is judged to be high. It has moderately

abundant amounts of organic material, contains extensive favorable rock types and is in a favorable topographic and stratigraphic position to receive uranium-bearing solutions derived from the weathering and erosion of the Hartford Hill Rhyolite. (Auth)

298
Curtis, N.M. (Comp.); Oklahoma Geological Survey, Norman, OK

Some Facts About Oklahoma Uranium. Oklahoma Geology Notes 16(10):107-120.(1956, October)

Uranium in the basal part of the undivided Permian Red Beds are associated with malachite and azurite, and in a few places the secondary uranium minerals, uranophane and carnotite, are visible. Analyses of selected samples from this area indicate a uranium content of 0.002 to over 1 percent U3O8. Asphalt bearing rock deposits studied indicated a uranium content in the ash of extracted oil of 0.054 - 0.001 percent uranium. Secondary uranium minerals are carnotite and autunite in the Wichita formation, and carnotite and tyuyamunite in the Quartermaster formation. Uranium-bearing asphalitic pellets along the flanks of the Anadarko Basin and the Wichita-Amarillo uplift may be related to the Permian sediments. Analysis of the pellets revealed uranium, vanadium, iron, nickel, cobalt, lead, and arsenic, with content ranging from 0.1 to 10 percent. (PAG)

299
Dahlkamp, F.J., and B. Tan; Uranezbergbau GmbH and Company, Bonn, Federal Republic of Germany

Geology and Mineralogy of the Key Lake U-Ni Deposits, Northern Saskatchewan, Canada. Geology, Mining and Extractive Processing of Uranium, Jones, M.J. (Ed.), Proceedings of a Symposium, London, January 17-19, 1977. Institute of Mining and Metallurgy, London, (pp. 145-157), 171 pp.(1976)

The Key Lake deposit is located at the southeastern rim of the Athabasca Basin in northern Saskatchewan. Both orebodies occur in approximately northeast-southwest-striking fracture zones, which affected the crystalline basement as well as the overlying Athabasca Sandstone Formation. The country rock comprises, from top to bottom, various deposits of glacial origin, the Athabasca Sandstone and metasediments of the Wollaston Fold Belt. The main mineralization consists of uranium oxides and nickel sulphides and arsenides. Rarely, some gangue occurs in the form of quartz and carbonates. Drilling results to date indicate, for the Gartner orebody, a length of 1500 m, a width of 10-40 m, a depth of 80 m and a grade of up to 45 percent U3O8 and 45 percent Ni; and, for the Deilmann orebody, a minimum length of 800 m, a width of 10 to more than 100 m, a depth of 150 m and contents of up to 20 percent U3O8 and 25 percent Ni. The thickness of the glacial overburden varies between 20 and 100 meters. The ore is tectonically and lithologically controlled. The presence of geothermometers, as tetragonal alpha-U3O7 (formation temperature, 135 degrees C) and bravoite (137 degrees C), in association with intergrowth textures of other ore minerals, points to a low-temperature origin. (Auth)(PAG)

300
Denson, N.M., J.R. Gill, and W.A. Chisholm; USGS, Washington, DC

Uranium-Bearing Lignite and Carbonaceous Shale in the Southwestern Part of the Williston Basin - A Regional Study with a Section on: Heavy Minerals in Cretaceous and Tertiary Rocks Associated with Uranium Occurrences. USGS Professional Paper 463; 75 pp.(1965)

Uranium in carbonaceous shale and lignite occurs at many horizons throughout 2,500 feet or more of Upper Cretaceous and lower Tertiary (Paleocene and Eocene) rocks in the southwestern part of the Williston Basin. The uranium occurrences extend northward 150 miles or more in general alinement with the structurally lowest part of the basin. The carbonaceous host rocks containing the higher grade occurrences range from 6 inches to 2 feet or more in thickness and are characterized by lenticularity, relatively high ash contents (35 to 40 percent), and low heating values. Although small amounts of uranium occur sporadically in carbonaceous rocks over a wide area along the southwestern part of the Williston Basin, the important reserves of ore-grade uraniferous lignite and carbonaceous shale containing greater than 0.1 percent uranium are present in the North Cave Hills and Slim Buttes areas of Harding County, South Dakota and in the Little Missouri River escarpment area (Rocky Ridge and Saddle Butte

localities) in eastern Billings and northwestern Stark Counties, North Dakota. In these areas blanket-type deposits, containing in excess of 150,000 tons of ore-grade material, and lentil-type deposits of higher grade material, containing a few hundred pounds to as much as 1,500 tons, have been reported. Some of the deposits in the Cave Hills and Little Missouri River escarpment areas are overlain by relatively thin overburden which make them amendable to strip mining. Inferred reserves of ore-grade material in the region exceed 1 million tons. Chemical analyses of 10 large samples of uranium-bearing lignite and carbonaceous shale from Billings County, North Dakota, indicate an average content of 0.18 percent uranium, 0.3 percent molybdenum, 0.09 percent phosphorus, and 0.01 percent vanadium. Only 2 of the 10 large samples analyzed contained less than 0.1 percent uranium. Primary structural and stratigraphic controls affecting the localization of uranium appear to be shallow troughs superimposed on the flanks of the basin by late Tertiary tectonic movements and by the proximity of the host rocks to the pre-Oligocene erosion surface. The localization of uranium in the Williston Basin is remarkably influenced by the presence of carbon, which has an affinity for uranium and which is effective as a reducing agent in causing the precipitation of uranium and associated metals from solution. Porosity of the lignitic host materials and the enclosing rocks are important secondary controls of mineralization. From a study of the spectrographic, chemical, and mineralogic data and of the principal structural and topographic relations of the deposits, we conclude that uranium, arsenic, molybdenum, selenium, vanadium, and some other elements were introduced into the lignite by ground water. Mineralization was probably continuous from Miocene to Present. The abundance of these elements in samples of ground water draining the Middle and Upper Tertiary tuffaceous rocks in the region and their presence in only minor amounts in ground water draining the underlying lignite-bearing sequence in unmineralized areas suggests an origin by leaching from the volcanic constituents composing the tuffaceous rocks. Other evidence supporting this mode of origin is the fact that all significant occurrences of uranium in the region fall to within about 200 feet stratigraphically of the base of the tuffaceous sequence or to its projected base in areas where erosion has removed the tuffaceous sequence. Microscopic studies of 135 grab samples from the continental basin-fill sedimentary rocks comprising the Hell Creek, Fort Union, Chadron, Brule, and Arikaree Formations reveal a characteristic heavy-mineral assemblage for each formation that differs from the assemblage in the adjacent formation. No relation was found between any of these assemblages and the occurrence of uranium. (Auth)(PAG)

301
Eakland, E.H., Jr.; Union Mines Development Corporation, Grand Junction Field Office, Grand Junction, CO

Report on Eurida (Toh Atin) District, Carrizo Uplift Area, Arizona. RMO-444; 39 pp.(1946, April)

Uranium-vanadium mineralization occurs in the Salt Wash Member of the Morrison Formation. In the Sweetwater Mesa locality fossil vertebrate bones are associated with the mineralization. Petrified logs are relatively rare but a few do occur associated with the ore in the Mexican Water locality. Six scattered ore occurrences are located in irregular bedded deposits of gray, vanadiferous clay with associated carnotite. The ore is most frequently found in the upper parts of the sandstone lenses, adjacent to thin shale seams. The length of the ore outcrop is much greater than the width, the ratio being about 30:1. In all cases, the ore horizon is about 0 to 20 feet stratigraphically above the Bluff-Salt Wash contact. (PAG)

Nineteen columnar sections are included in this report.

302
Everhart, D.L.; AEC, Raw Materials Division, Washington, DC

Radioactive Mineral Deposits in Dickinson County, Michigan. RMO-984; 11 pp.(1952, August)

Dark red metamorphosed Laurentian granite is intersected by a fracture zone that is mineralized with hematite coatings and which, by field instruments, exhibits anomalous radioactivity. Selected samples of the most radioactive material assay 0.06 percent U3O8 radiometrically and 0.014 percent U3O8 chemically indicating that most of the radioactivity is due to small concentrations of thorium. Claim No. 2 is characterized by a fracture zone cutting massive black biotite schist, parallel to a contact with coarse-grained granitic gneiss of the Laurentian formation. Radioactivity

ranging from 3 to 10 times background is registered for 30 feet along the fracture. A few tons of rock have been blasted from a prominent outcrop along the zone, and samples of the most radioactive and freshly blasted rock adjacent to the fracture assay 0.02 percent U3O8 radiometrically and 0.008 percent U3O8 chemically. Claim No. 3, lying about 1200 feet northeast of No. 2, is very similar geologically and picked samples of the most radioactive rock in a 50 foot mineralized fracture zone assay 0.02 percent U3O8 radiometrically and 0.002 percent U3O8 chemically. (Auth)(MLB)

303
Fisher, W.L., C.V. Proctor, Jr., W.E. Galloway, and J.S. Nagle; Texas Bureau of Economic Geology, University of Texas, Austin, TX

Depositional Systems in the Jackson Group of Texas-Their Relationship to Oil, Gas, and Uranium. Circular 70-4; 28 pp.; Gulf Coast Association of Geological Societies Transactions 22:234-261.(1970, October)

Five main depositional systems of the Jackson Group in Texas are delineated through regional outcrop and subsurface investigation. The dominant element in the central and eastern Texas Gulf Basin is the Fayette fluvial-delta system (bounded by Guadalupe River on the south and Neches River on the east) consisting of dip-oriented, lobate wedges of sands, muds, and lignites. Vertical sequence in updip subsurface and outcrop grades upward from marine muds through delta facies into fluvial sands and muds, reflecting net regression and progradation of the system. Longshore drift of sediments from the delta system contributed to the South Texas strandplain-barrier bar system, consisting of strike-trending sand bodies interbedded with marine and lagoonal muds. Landward of the strandplain-barrier bar system and extending into the outcrop is a lagoonal-coastal plain system consisting of muds, local lignites, and minor, dip-oriented channel sand units. Gulfward of the strike-trending strandplain system is the South Texas shelf system, formed of marine muds derived largely from the delta system to the northeast. Beneath the South Texas strandplain-barrier bar and Fayette delta systems and extending eastward into Louisiana and Mississippi is the Yazoo-Moodys Branch shelf system consisting of marine, fossiliferous muds and minor glauconitic marls. Texas Jackson delta and associated systems are comparable to depositional systems of other Eocene units (Lower Wilcox and Yegua) of the Gulf Basin as well as the Holocene Mississippi delta and related systems of the northwestern Gulf of Mexico. Delineation of depositional systems and component facies facilitate definition of significant mineral trends (oil, gas, lignite, and uranium) that show the relationship between existing and potential areas of production. (Auth)

304
Galloway, W.E., and C.G. Groat; Texas Bureau of Economic Geology, University of Texas, Austin, TX

South Texas Uranium Province: Geology and Extraction. Research Note 6; 11 pp.(1976)

All principal upper Tertiary sand units in the south Texas area host uranium resources. The elongate and sinuous ore bodies occur along laterally continuous mineralization fronts; width of the ore zone rarely exceeds 200 feet. Common accessory materials include organic matter, pyrite, zeolite, clay minerals, and calcite. Volcanic ash interbedded with the Tertiary units provides the source of uranium. Ore grades range from a few tenths to a few hundreds of a percent U3O8. More than ten million pounds of U3O8 have been extracted by surface mining and in-situ leaching. The in-situ recovery process, unique to the Texas Coastal Plain, and surface mining are represented schematically. (PAG)

305
Goldstein, E.H.

Geology of the Dakota Formation Uraninite Deposit Near Morrison, Colorado. Economic Geology 52(7):775-785.(1957, November)

Along the front range of Colorado, uranium ore has been found both in Precambrian rocks and sedimentary rocks. The Precambrian rocks consist of metasediments and intrusive batholithic granites. The sediments range from Pennsylvanian to Tertiary in age. Uranium ore is found in the upper Muddy sandstone member of the Dakota formation in close association with asphalt, pyrite, and ilsemannite (molybdenum oxide) and is controlled by a west dipping strike-slip fault. The ore body occupies a position adjacent to and in the footwall side of the fault, and traces of uranium are found on the hanging wall side. Uranium is also found in the lower

sandy portion of the Skull Creek shale. The uraninite is believed to be a primary ore of hydrothermal origin. It is further suggested that uranium-bearing hydrothermal solutions originated in the Precambrian complex and migrated eastward along the Golden thrust fault. The Golden thrust fault, which underlies the area, therefore served as a conduit for the solutions. The solutions then migrated into minor shear zones that intersect the main Golden thrust fault, and where these minor faults traversed permeable sandstone, the solutions impregnated the sandstone. Uranium was then precipitated from the hydrothermal solutions when favorable conditions for deposition, such as asphaltum, were encountered. (Auth)(M.B)

306
Gornitz, V., and P.F. Kerr; Columbia University, New York, NY

Uranium Mineralization and Alteration, Orphan Mine, Grand Canyon, Arizona. Economic Geology 65(7):751-768.(1970, November)

The Orphan Mine uranium orebody occurs in a nearly circular, vertical pipe structure, which ranges from about 150 to 500 feet in diameter. The pipe extends downward from the lower part of the Coconino Sandstone into the Supai Formation and may continue down into the Redwall Limestone. The pipe fill consists of downward displaced massive Coconino Sandstone, angular siltstone, shale and limestone breccia from the Supai and Hermit Formations. There is no intrusive material within the pipe, and therefore, a direct igneous origin is unlikely. The pipe probably formed by solution collapse initiated in the underlying Redwall Limestone. Uranium ore is concentrated in places along the pipe border and is distributed in irregular masses within the pipe. Uraninite and pyrite at the center of the pipe grade into a complex mixture of chalcocite, tennantite, chalcopyrite, galena and uraninite at the margins. Elements such as Mo, Co, Ni, As, Mn, and V appear in minor quantities, but Th and the rare earth group have not been detected. Effects of alteration include bleaching of normally red Supai Sandstone near the contact and within the pipe, carbonatization, and development of hematitic haloes around uraninite. Significant argillic alteration has not been observed. Temperatures of ore deposition as suggested by fluid-inclusion thermometry of calcite proved to be 60 to 110 degrees C. These were somewhat higher than the 58 plus or minus 5 degrees C, that was estimated from the burial of sediments and the geothermal gradient. A minimum age of about 141 million years has been furnished by U/Pb dating. Sulfur isotope ratios show enrichment in S-32 over S-34. The pipe structure and mineral distribution suggest a hydrothermal origin, but a direct unmixed magmatic source is improbable. The ore solutions may have originated in a distant hydrothermal source and in moving upward mingled with groundwater. (Auth)

307
Harshman, E.N.; USGS, Washington, DC

Geology and Uranium Deposits, Shirley Basin Area, Wyoming. USGS Professional Paper 745; 77 pp.(1972)

The Shirley Basin contains one of the major uranium ore reserves in the United States. Rocks in the Shirley Basin area range in age from Precambrian to Quaternary. The Precambrian rocks crop out in the core of the Laramie Mountains and are part of an ancient terrane that was folded, metamorphosed, and subsequently invaded by granitic batholiths and mafic dikes. The intrusive activity was followed by a long period of erosion, and by the end of Precambrian time, the region was reduced to a nearly flat surface. Throughout the Paleozoic Era and much of the Mesozoic, the area was part of the stable foreland that lay along the east side of the Cordilleran geosyncline. Epicontinental seas repeatedly transgressed the area from the west and northwest, leaving a thick series of marine, littoral, and continental sediments deposited. Near the end of the Jurassic Period the western shores of the epicontinental seas migrated eastward, and great amounts of clastic material, eroded from highlands to the west, were deposited along the shores of, or in, the Cretaceous seas. The Laramide orogeny deformed the area at the close of the Cretaceous, and the seas withdrew for the last time. Erosion of the newly formed mountains began in the Paleocene and continues now. The clastic debris that had been eroded from the highlands to the east and west of the Shirley Basin was deposited on an erosional surface which was cut into Cretaceous and older rocks. The pre-Tertiary rocks have been folded and faulted on a minor scale. The ground water table in the area lies from a few feet to 100 feet or more below the surface. Ground water is tributary to the surface drainage system and has a southerly gradient of 10 to 30 feet per mile. The principal

anions in the ground water are sulfate and bicarbonate; radioelements include uranium, radium, and radon. Measurements of pH range from 6.6 to 8.3 and have a mean and median of about 7.7. The uranium deposits in the Shirley Basin constitute about one-sixth of the Nation's ore reserves. They are in the Wind Basin River Formation of early Eocene age in two thick sandstone intervals which are separated by siltstone and silty claystone beds. The deposits bound large tongues of altered sandstone, commonly in roll forms at the margins and as tabular layers on the top and bottom surfaces, a spatial relationship useful as an exploration guide. Ore bodies range from a few hundred tons to a few hundred thousand tons and in ore grade, as mined, from 0.1 to 0.7 percent U3O8. High-grade ore may contain as much as 20 percent U3O8. The edges of the altered-sandstone tongues in the Shirley Basin area separate oxidized iron minerals in the material surrounding them. For this and other reasons, the ore-bearing solutions that produced this alteration are thought to have been oxidizing. The geochemistry of the ore and associated minerals and the arkosic nature of the ore-bearing sandstones suggest that these solutions were alkaline. Hydrogen sulfide of biogenic origin is believed to have played an important part in forming the ore deposits, although precipitation of the ore minerals may have been caused by nonbiogenic reactions. Ore deposition probably took place at least 500 feet and perhaps as much as 1,500 feet below the ground surface. Uraninite is the only identified ore mineral; accessory minerals are abundant amounts of pyrite and minor amounts of marcasite, calcite, hematite, and an unidentified sulfate mineral. The age of the Shirley Basin uranium deposits is not well documented, but the best evidence suggests that it is about 18 million years. (JMT)

308

Harshman, E.N., and K.G. Bell; USGS, Washington, DC

Uraninite-bearing Contact Metamorphic Deposits, Heaths Peak, Carbon County, Wyoming. Economic Geology 65(7):849-855.(1970, November)

At Heaths Peak locality in the Pedro Mountains, Carbon County, Wyoming, some small, but geologically interesting, sulfide mineral and uraninite deposits are found in the contact zones between granite of Precambrian age and roof pendants of regionally metamorphosed rock. The deposits are interesting because they display a zoned distribution of metals from the edge of granite into adjacent remnants of regionally metamorphosed rocks. Their small size may be attributed to: (1) a "dry" magma that produced a very narrow hydrothermally altered aureole along its contacts, and (2) intruded metamorphic rocks that had low reactivity to magmatic solutions. The metallic minerals - uraninite, molybdenite, pyrite, chalcopyrite, galena, pyrrhotite, and marcasite - are concentrated on the undersides of metamorphosed roof pendants. (JMT)

309

Hegge, M.R.; Pancontinental Mining Limited, Sydney, Australia

Geologic Setting and Relevant Exploration Features of the Jabiluka Uranium Deposits. The Australian Institute of Mining and Metallurgy Transactions 264:19-32.(1977, December)

The Jabiluka One and Two uranium deposits occur in Lower Proterozoic metasediments of the Cahill Formation which is part of the Pine Creek Geosyncline in the East Alligator River area, Northern Territory. The Jabiluka One deposit coincides with a window through unconformably overlying Middle Proterozoic sandstone of the Kombolgie Formation while Jabiluka Two is completely covered by the sandstone. The observed part of the Cahill Formation exhibits four horizons which are favorable hosts for uranium mineralization. These have been folded into an east-southeast striking, gently plunging, open asymmetric syncline-anticline structure. The host rocks are mainly chlorite and/or graphite schists and their brecciated equivalents which have undergone the initial prograde metamorphism to the amphibolite facies, then retrograde metamorphism to the greenschist facies. Mineralization consists of open space filling pitchblende and lesser disseminated material. Chlorite, pyrite, and quartz are commonly associated with the uranium mineralization. A portion of the Jabiluka Two deposit contains economic concentrations of gold. Structural preparation with low pressure conditions at these sites appear to be the most significant ore control. Genetic hypotheses favor initial deposition in Lower Proterozoic sediments, then remobilization during later orogenic events. The deposits bear a marked similarity to some pitchblende deposits in central Canada. (Auth)

310
Hetland, D.L.; AEC, Division of Raw Materials, Salt Lake Exploration Branch, Salt Lake City, UT

Preliminary Report on the Buckhorn Claims, Washoe County, Nevada and Lassen County, California. RME-2039; 17 pp.(1955, August)

Features which may have a direct or indirect bearing on the interpretations of both the origin and the potential of the deposit in the Buckhorn group of mining claims are: 1) the uranium occurs in small siliceous veinlets along NE-trending fractures, 2) banding of the veinlets is apparent in some hand specimens, 3) the mineralized rocks grade into barren rocks of apparently the same composition, 4) the anomalous radioactivity is confined to Tertiary volcanics of rhyolitic composition 5) major faulting in late Tertiary time is suggested by the stream channels, physiography, and attitude of the volcanics overlying the granite, and 6) several other uranium occurrences have been discovered in the Tertiary volcanics, both to the north and south over a distance of about 10 miles. The estimated ore reserves on the Buckhorn group of claims are 310 tons of indicated ore at 0.25 percent and 2,700 tons at plus 0.10 percent uranium oxide. The inferred tonnage estimated for the property is 3,115 tons at an average grade of 0.11 percent uranium oxide. (PAG)

311
Hetland, D.L.; AEC, Division of Raw Materials, Salt Lake Exploration Branch, Salt Lake City, UT

Preliminary Report on the Uranium Occurrence of the Green Velvet Claims, Inyo County, California. RME-2045; 17 pp.(1955, October)

Several uranium occurrences were discovered in the Coso lake beds, Owens Valley, California, along the west flank of Coso Range. The most significant deposit is situated on the Green Velvet claims. Autunite occurs on fracture surfaces and in iron-stained zones. The most significant feature of this occurrence is the lateral extent of mineralized strata which can be traced for 2,200 feet. Select samples contain ore-grade material. Significant uranium concentrations are associated with prominent iron-stained zones in the area. (MLB)

312
Hilpert, L.S., and R.H. Moench; USGS, Grand Junction, CO

Uranium Deposits of the Southern Part of the San Juan Basin, New Mexico. Peaceful Uses of Atomic Energy, Proceedings of the 2nd International Conference, Geneva, September 1-13, 1958. United Nations, Vol. 2, Survey of Raw Material Sources, (pp. 527-538), 843 pp.(1958)

Rocks exposed along the southern margin of the San Juan Basin consist of sedimentary strata ranging in age from Permian to Cretaceous, and intrusive and extrusive rocks of Tertiary and Quaternary ages. The uranium deposits along the southern margin are those in sandstones and associated mudstones of the Entrada, Morrison and Dakota formations; those in the Todilto limestone; and one deposit in a pipelike structure. The Entrada sandstone, a reddish-orange, fine-grained, quartzose sandstone contains a few small deposits in the top of the formation. The Todilto limestone, overlying the Entrada, is fine-grained and thinly bedded in the lower part and medum-grained and massive in the upper part. Uranium deposits in the Todilto range from small to fairly large, and are localized where the limestone beds are deformed by folding and faulting. The Summerville formation contains uranium ore only in beds immediately adjacent to deposits in the Todilto. The Morrison formation contains most of the uranium deposits in the area. The ore-bearing sandstones are in thick layers, with cross-bedding of the fluvial type, intercalated with thin and discontinuous claystone lenses, and contains carbonaceous material. The Dakota sandstone, a fine- to medium-grained sandstone with carbonaceous shale and coal at the base, contains small deposits in the carbonaceous beds. The unique sandstone pipe is a heterogeneous mixture of sandstone and mudstone with abundant carbonaceous materials. The ore is exceptionally high grade in the upper part of the pipe with ore concentration around the ring fault. (PAG)

313
Houston, R.S., and J.R. Murphy; University of Wyoming, Laramie, WY

Titaniferous Black Sandstone Deposits of Wyoming. Geological Survey of Wyoming Bulletin No. 49; 120 pp.(1962, November)

Fourteen black sandstone deposits in Wyoming were examined and the results of the study are given in this report. These sandstones are highly indurated concentrations of heavy minerals that accumulated as ancient beach placers. With the exception of one deposit of Late Jurassic age, all known black sandstone deposits in Wyoming are in rocks of Late Cretaceous age. The heavy minerals, which comprise as much as 80 percent of the black sandstone, include anatase, apatite, biotite, chlorite, rutile, sphene, spinel, staurolite, tourmaline, zircon, and radioactive opaque minerals. Ilmenite, "ferrian ilmenite," monazite, rutile, zircon, and the radioactive opaque minerals have potential economic value. The partially altered "ferrian ilmenite" is the most abundant mineral in the deposits and has TiO2 contents averaging 35 to 40 percent. Monazite, rutile, and the radioactive opaque minerals occur in minor amounts but may be valuable as by-products. (JMT)

314
Kaiser, E.P.; USGS, Washington, DC

The Papsy's Hope Autunite Prospect, Marysvale District, Piute County, Utah. TEM-145A; 10 pp.(1952, January 7)

The deposit at the Papsy's Hope autunite prospect is in feldspar porphyry of the older Tertiary (Bullion Canyon) volcanics. The intrusive quartz monzonite that contains the deposits is in contact with a quartz porphyry similar to the rocks exposed about 1,500 feet west of the Papsy's Hope prospect. Samples across the autunite-bearing zone average 0.026 percent equivalent uranium. The prospect is immediately beneath the old erosion surface at the base of the younger Tertiary volcanics. The younger volcanics are still present a short distance to the north and south of the Papsy's Hope prospect. The deposit is associated with completely silicified outcrops. (PAG)

315
Keith, S.B.; Union Mines Development Corporation, Grand Junction Field Office, Grand Junction, CO

Report on Lightner Creek District, San Juan Basin Area, Colorado. RMO-453; 21 pp.(1945, December)

A survey of the Lightner Creek District, San Juan Basin Area, Colorado was made to determine the form of occurrence, tonnage, and grade of radioactive ores. Vanadiferous sandstone occurs in the upper part of the Entrada sandstone, from 2 to 4 feet below the Todilto limestone. The average thickness of the ore horizon lens is estimated to be about 0.3 feet. The ore bodies may be in the form of even bands, lenses, pods, or rolls and usually occur as a combination of several forms. The distribution of the ore and the character and form of the ore horizon suggest an elongated flat lens with the long axis oriented in a NW direction and roughly parallel to the trend of the regional dip. In this area, 25,580 short tons of ore are estimated to be present, but it is possible that further study will show that the ore resources are higher than the estimated values. (PAG)

316
Kern, B.F.; Idaho Bureau of Mines and Geology, Moscow, ID

Geology of the Uranium Deposits Near Stanley, Custer County, Idaho. Pamphlet No. 117; 40 pp.(1959, June)

The Stanley uranium area is in T11N, Ranges 13 and 14E, Custer County, Idaho. The basement complex, predominantly quartz monzonite of Cretaceous age, is called the Idaho Batholith. The Tertiary (Oligocene-Miocene) Challis Volcanics unconformably overlies the basement, and consists of 2000 feet of flows and tuffs of intermediate composition. A 100-foot basal sequence of terrestrial clastics is also present. Fractures are the primary structural feature which control the distribution of uranium ore deposition. Uranium also occurs in silicic intrusives and disseminations in the arkosic conglomerates at the base of the Challis. Several factors indicate hydrothermal origins for the uranium deposits: structural control by fractures; hydrothermal alteration of host rocks; and the presence of uraninite, stibnite, marcasite, and chalcedony gangue in some of the vein deposits. Over 230 claims were staked, which comprise 16 different groups, each of which is discussed. (MBW)

317
King, R.U.; USGS, Washington, DC

Investigations in the Wood Mine, Colorado. TEM-102A; 1 pp.(1951, December)

During the latter part of January 1950, geologic reconnaissance investigations at the Wood mine

on Quartz Hill, Gilpin County, Colorado, were resumed when the upper levels were made accessible by the operators and lessees. The Wood mine was selected for further examination because of known production of pitchblende, high radioactivity noted on the dump and in the uppermost workings, and because of its proximity to the Calhoun mine, where previous reconnaissance work had been done. The country rock in the vicinity of the Wood mine is Precambrian granite gneiss with scattered inclusions of biotite schist. The mine is on an east-west fault-fissure vein that is generally vertical, but locally dips from 75 degrees north to 75 degrees south. The vein cuts diagonally across the foliation of the gneiss. It includes a bleached, fine-grained (kaolinized) gneiss, with disseminated pyrite and local areas of sericite, surrounding a core 1/8 inch to 1 foot wide of massive granular pyrite and sphalerite in quartz. This part of the vein contains scattered tetrahedrite, chalcopyrite, covellite, and chert. In a few places pitchblende is visible as small blebs as much as 5 mm in size, and as veinlets, up to 1/8 inch in width. During the underground mapping, pitchblende was observed in three places at the 135-foot level. Those occurrences are to the east of, and within 20 feet of, the shaft, and over a vertical range of about 15 feet. On the 195-foot level three occurrences of pitchblende were noted in the drift just west of the shaft. These are scattered over a 45-foot interval. These occurrences are in both a subsidiary vein and the main Wood vein. Samples of the Wood dump show a great discrepancy between the radioactivity and the uranium content. Three samples from the Wood dump were taken during reconnaissance studies in 1949 and gave the following results: 1.03 percent eU - 0.002 percent U; 0.055 percent eU - 0.002 percent U; 0.005 percent eU - 0.001 percent U. (MLB)

318
King, R.U., and H.C. Granger; USGS, Washington, DC

Torbernite Occurrence at the Robineau Claims, Clear Creek County, Colorado. TEM-24A; 7 pp.(1952, January 25)

The Robineau claims include the George Peabody, MacGregor, and Little Mac claims in Clear Creek County, Colorado. Fractured, iron-stained granite pegmatite from shallow shafts on the George Peabody claim and several prospect pits on the other claims were prospected. Due to inaccessibility of the workings at the time of examination (1949), radiometric traverses were made of the area covered by the claims, and the dump at one shaft was sampled. Torbernite and an unidentified radioactive mineral are associated with hydrous iron oxides on fracture surfaces in pre-Cambrian granite and pegmatite. A composite sample of waste rock taken seven parts of the George Peabody dump contained 0.013 percent U308. Radioactivity of most of the prospect pits is slightly higher than background. (Auth)(PAG)

319
Kirkpatrick, R.K.; Union Mines Development Corporation, Grand Junction Field Office, Grand Junction, CO

Report on Gypsum Valley District, Dolores Plateau Area, Colorado. RMO-443; 58 pp.(1946, April)

A reconnaissance survey was conducted on the Gypsum Valley District, Colorado in an effort to record the vanadium mineralization and deposits of the area, and to estimate the ore reserves. The Gypsum Valley District is an unusually complex area due to the principal and subsidiary folding and corollary faulting incident to the formation of the Gypsum Valley anticline, and the subsequent collapse of its crest area into the graben now occupied by the Gypsum Valley. Faults were difficult to interpret due to a number of wide unconformities between formations. The vanadium ore of the district usually occurs as bedded type deposits in the Salt Wash member of the Morrison formation. In places, secondary vanadium mineralization is found along fault zones in the Salt Wash and the older formations. The mineralogy of most of the ore is similar to that of the common carnotite-type vanadium deposits of the Colorado Plateau. Sandstones and clays are impregnated with dark-gray vanadium-bearing minerals. The deposits are distributed over much of the district, although those on the north side of the valley are by far the most important. The potential reserves of the district are approximately 50,000 tons of ore. (PAG)(MBW)

320
Lewis, R.Q., Sr., and R.H. Campbell; USGS, Washington, DC

Geology and Uranium Deposits of Elk Ridge and Vicinity, San Juan County, Utah. USGS Professional Paper 474-B; 68 pp.(1965)

Uranium ore is produced almost exclusively from fluvial sandstone beds at the base of the Chinle Formation. In the southwestern, central, and eastern parts of Elk Ridge the host beds are sandstone lenses at the base of a unit that is predominantly mudstone. In the northeastern part of the area, where the mudstone unit is generally thin and locally absent, sandstone of the overlying Moss Back Member of the Chinle Formation is the host rock. Where the lowermost beds of the Chinle Formation are exclusively mudstone no uranium ore has been found. As a result, the Elk Ridge area includes two ore-bearing parts: a beltlike area that trends west-southwest across the central part of Elk Ridge; and an irregular area to the northeast, separated from the central belt by a generally barren area. The ore deposits are in lenticular beds of sandstone and conglomeratic sandstone that have been deposited in and built up above shallow paleostream channels cut into the top of the Moenkopi Formation. The ore deposits are generally flat-lying lenticular bodies, and are commonly elongated in the direction of the channels, but there are many local variations in shape and dimension. The grade of ore deposits generally is not uniform. Run-of-mine ore is generally a mixture of high-grade ore to barren material. The areal distribution of the ore deposits appears to be controlled by the distribution of fluvial sandstone at the base of the Chinle Formation. The outlines of the central belt indicate approximately the limits of distribution of channel sandstones at the base of the mudstone unit of the Chinle Formation. The southwestern outline of the northeastern area of ore-bearing rocks indicates approximately the southwestern limit of an area where sandstones at the base of the Moss Back Member have been deposited in channels cut through the underlying mudstone unit and lie directly on the Moenkopi. No ore deposits are known to occur in Chinle sandstones that are not in contact with the Moenkopi Formation, although small amounts of low-grade material occur in some stratigraphically higher beds of the Chinle. Ore deposits in the lenses of permeable channel sandstone are almost invariably overlain by mudstone or very argillaceous sandstone lenses. The ore-bearing sandstone lenses also appear to grade longitudinally and laterally into less permeable argillaceous sandstone and mudstone. The only major structural control for ore deposits indicated is that which controlled the deposition of the favorable host rocks of the central belt. Considering the shallow nature of the channel scours into the top of the Moenkopi Formation (generally less than 10 feet deep), and considering the relatively uniform thickness of Moenkopi as opposed to the variations in thickness of the Chinle mudstone unit, the depositional basin that received the pre-Moss Back Chinle sediments appears to have been controlled by a structural trough of early Chinle, post-Moenkopi time. It is believed that the central favorable belt probably represents the position and direction of the deepest part of the structural basin. The regional stratigraphic associations of the ore deposits suggest that the solutions from which the ore was deposited were introduced into the host beds from their areas of contact with the underlying Moenkopi Formation. The detailed stratigraphic setting of the ore bodies suggests ascending solutions were impounded by overlying impermeable barriers. This would require an important ascending component to their direction of flow. Dilute, virtually nonreactive, low-temperature ore solutions might have passed along the Moenkopi-Chinle contact, or even upward through the Moenkopi and older rocks, leaving little or a trace. Impermeable barriers above the ore-bearing parts of the host sandstones were probably an important control for the deposition of ore minerals from solution. Organic material is associated with ore in many places and may have facilitated deposition.Overlying impermeable barriers may have served as semipermeable membranes at which hypofiltration of metallic constituents from ascending solutions took place. Alternatively, or perhaps in combination, impermeable barriers may have formed stratigraphic traps for H_2S gas or fluid hydrocarbons and thus localized a reducing chemical environment in which ore minerals were later precipitated. (Auth)(PAG)

321

Livingston, C.W.; Union Mines Development Corporation, Grand Junction Field Office, Grand Junction, CO

Report on West Paradox District, Dolores Plateau Area, Colorado-Utah (Figures and Columns). RMO-456; 27 pp.(1945, October)

Uranium-vanadium ore is of variable texture and is found predominantly as fine-grained sandstone, but grades to conglomberate. Stratigraphic position of the ore is presented in five figures. Columnar sections for twenty areas are included in this report. (PAG)

Twenty columnar sections are included in this report.

322
Love, J.D.; USGS, Washington, DC

Uranium in the Mayoworth Area Johnson County, Wyoming - A Preliminary Report. USGS Circular 358; 7 pp.(1954)

Metatyuyamunite occurs in the basal limestone of the Sundance Formation of Late Jurassic age along the east flank of the Bighorn Mountains, about 2 miles southwest of the abandoned Mayoworth post office. The deposit is the first occurrence of uranium mineralization reported from a marine limestone in Wyoming. The metatyuyamunite is concentrated in a hard gray oolitic limestone that forms the basal bed of the Sundance Formation. A selected sample of limestone contained 0.71 percent uranium. Eight samples of limestone taken at the same place contained from 0.007 to 0.22 percent uranium. A chip sample from a weathered outcrop contained 0.030 percent uranium, and a dinosaur bone from the middle part of the Morrison Formation contained 0.004 percent uranium. Metayuyamunite forms a conspicuous yellow coating along fracture planes cutting the oolitic limestone, and has replaced many of the oolites within the solid limestone. (JMT)

323
Love, J.D.; USGS, Washington, DC

Preliminary Report on Uranium in the Gas Hills Area, Fremont and Natrona Counties, Wyoming. USGS Circular 352; 11 pp.(1954)

Uranium minerals in the Gas Hills area occur in the Wind River Formation of early Eocene age and in the Thermopolis shale of early Cretaceous age. The uranium is concentrated in clayey and conglomeratic sandstones and in carbonaceous shale. Several selected samples of sandstones from the Wind River Formation contain more than 10 percent uranium. The highest analysis of a channel sample is 6.72 percent uranium from a 1-foot section of conglomeratic sandstone in the Wind River Formation. The highest analysis of a carbonaceous shale in this formation is 0.062 percent uranium. Several uranium minerals are present in the deposits, the dominant one being meta-autunite. The author believes that the source of the uranium may have been tuff in the White River Formation (Oligocene) or younger Tertiary rocks that once overlaid this portion of the Wind River Basin. The available evidence suggests that the uranium was carried downward and laterally along sandstone aquifers in the middle Eocene sequence and Wind River Formation, concentrating in favorable host rocks. (JMT)

324
Love, J.D.; USGS, Washington, DC

Uraniferous Phosphatic Lake Beds of Eocene Age in Intermontane Basins of Wyoming and Utah. USGS Professional Paper 474-E; 66 pp.(1964)

Syngenetic concentrations of uranium and phosphate occur in thin persistent lacustrine zones of Eocene age in four areas in SW and C Wyoming and in the Uinta Basin of Utah. In the Green River area, the Wilkins Peak Member of the Green River Formation contains more than 35 radioactive zones, of which 25 are known to be uraniferous and phosphatic. The member, which is of late Early Eocene and Middle Eocene age, is about 1,000 feet thick, and is composed of highly tuffaceous lacustrine dolomite marlstone, limestone, claystone, shale, siltstone, sandstone, trona beds, and oil shale. Maximum uranium content is 0.15 percent and P_2O_5 is 18.2 percent. Average for the 25 sampled zones, which range in thickness from 3 inches to 6 feet, is about 0.005 percent uranium and 2.2 percent P_2O_5. In the Pine Mountain area, there is one uraniferous phosphatic zone from a few inches to more than 4 feet thick in sandstone and siltstone in the lower part of the Cathedral Bluffs Tongue (Eocene) of the Wasatch Formation. Maximum uranium content is 0.29 percent, and P_2O_5 is 19.04 percent. Average of all 20 samples from the zone is 0.06 percent uranium and 5.7 percent P_2O_5. In the Beaver Divide area of SC Wyoming, the middle and upper Eocene rocks consist of green and brown fine-grained tuffaceous claystone, carbonaceous shale, siltstone, and sandstone. These strata contain 7 or more radioactive zones, 5 of which have at least 1 percent phosphate. The thickness of these zones ranges from a few inches to 2 feet. Maximum uranium content is 0.042 percent, and P_2O_5 is 5.67 percent. In the Lysite Mountain area of NC Wyoming, seven uraniferous phosphatic zones ranging in thickness from a few inches to several feet were sampled. Four zones are in the Aycross equivalent of probable Middle Eocene age, and three are in the Tepee Trail equivalent of Late Eocene age. Maximum uranium content is 0.040 percent, and P_2O_5 is 7.25 percent. The zones are part of an oil shale and analcitized tuffaceous lacustrine sequence. The Green River Formation in the Uinta Basin of NE Utah, as

much as 7,000 feet thick, is lithologically similar to that formation in the Green River Basin of Wyoming, and likewise contains many radioactive zones. One has 0.07 percent uranium and 8 percent P2O5. A lithologically similar section, 2,000 feet thick, of the Green River Formation is present in the Piceance Creek Basin of northwestern Colorado. The origin of the uraniferous phosphatic zones is unknown. Inasmuch as trona is associated with them only in the Green River Basin, evaporitic environment is apparently not necessary for the concentration of uranium and phosphate. The Wilkins Peak Member contains abundant dacitic-andesitic volcanic debris, and igneous rocks of this general composition contain about 0.003 percent uranium and 0.2 percent phosphate. The strata between the zones have so little uranium and phosphate that the member as a whole contains no more of these elements than the "average" shale. Therefore, the presence of the zones does not necessarily require either sporadic floods of uranium- and phosphate-rich debris from adjacent exposed source rocks or wind- or water-borne volcanic ash abnormally rich in these elements. The zones may well have developed entirely as a result of unique geochemical conditions that were widespread only during parts of Eocene time. (Auth)(PAG)

325
Lovering, T.G.; USGS, Washington, DC

Radioactive Deposits in New Mexico. USGS Bulletin 1009-L; 74 pp.(1956)

Of the New Mexico uranium deposits known in 1952, only those in the Grants district of Valencia and McKinley Counties have proven reserves of uranium ore. The carnotite deposits of the Carrizo Mountains area, San Juan County, are mostly small and widely scattered, but many of them contain pockets of high-grade ore and it is probable that small quantities of uranium ore will be produced from them for some time. The deposits of autunite and torbernite in the White Signal District may also become commercially important, as may the uranophane deposits at Monticello. The pegmatites near Petaca do not contain sufficient quantities of uranium and thorium minerals to be minable for these elements alone, but it is possible that they could be economically recovered as by-products from the production of beryl. The low-grade uranium-bearing copper deposits in Mora, Rio Arriba, and Sandoval Counties might become of interest economically if the copper could be mined and the uranium recovered as a by-product. With the possible exception of La Ventana Mesa, the radioactive coal, black shale, and hot spring deposits are of little economic interest. (JMT)

326
Marks, L.Y.; AEC, Production Evaluation Division, Grand Junction Office, Grand Junction, CO

Preliminary Report on Uranium-Bearing Deposits of the Ollie-Carlyle District, Southeastern Montana. TM-D-1-11; 35 pp.(1959, May)

Uranium has been discovered in rocks of the Fort Union Formation of Paleocene age in the Ollie-Carlyle district, southeastern Montana. The host rocks are probably part of the Tongue River member. Where favorable for uranium, they consist of sandy strata containing carbonaceous trash and lignitic beds and lenses, and are underlain by impermeable clays. Structure probably contributed to localization of uranium, as deposits are down dip from local structural highs. The uranium appears to be in equilibrium below the water table but not near the surface. Uranium may be partly in urano-organic compounds or complexes, but metatyuyamunite and possibly meta-autunite have been found in the zone of oxidation near the surface. Ground water is considered to be the agent that deposited and redistributed the uranium, which was possibly leached from tuffaceous rocks of Oligocene and Miocene age. (Auth)

327
McMillan, R.H.; Western Mines Limited, Toronto, Ontario, Canada

Uranium in Canada. Bulletin of Canadian Petroleum Geology 25(6):1222-1249.(1977, December)

Uranium ore deposits can be classified into three major types: detrital, hydrogenic and igneous-metamorphic. Although some igneous-metamorphic deposits formed as primary concentrations, detrital and hydrogenic deposits formed as secondary concentrations at or near the surface of the earth's crust-the uranium having been initially exposed to the surficial environment in felsic intrusive and volcanic rocks in concentrations generally less than 50 ppm. Canada is favored with uranium ore reserves

which are among the largest in the world–these reserves are contained in all three types of deposits. The igneous-metamorphic type is represented by the Bancroft district of Ontario, where more than 11 million pounds U3O8 have been produced from pegmatites emplaced in granulite-facies metamorphic rocks. The detrital deposits of Elliot Lake, with production in excess of 190 million pounds of U3O8 by 1976, constitute one of the largest uranium ore districts in the world. The Elliot Lake deposits and a similar deposit at Agnew Lake occur in pyritic quartz pebble conglomerates which were deposited in paleo-stream channels. These deposits were derived from uranium-rich granitic rocks located north of the depositional area and concentrated mainly as detrital heavy minerals. Hydrogenic uranium deposits are represented in the Proterozoic of Canada in shales and several epigenetic types. The epigenetic deposits are generally characterized by pitchblende and hematite and are generally enriched in Ni, Co, Ag, Cu and As. Chemically favorable graphitic and (or) calcareous shelf-facies metasedimentary strata commonly form the host rocks. The Port Radium and Beaverlodge deposits are "classical" veins which exhibit strong structural control. Stratigraphic control appears more important in the recently discovered "unconformity-veins" which occur near the base of the Athabasca Sandstone in Saskatchewan. At the Rabbit, Key and Cluff Lake deposits most of the mineralization occurs in basement rocks within 100 m of the unconformity, but ore is also found within the regolith and overlying orthoquartzites. Production from the Athabasca area deposits will probably surpass that from the Elliot Lake district in the future. (Auth)

328
McMillan, R.H.; Western Mines Limited, Toronto, Ontario, Canada

Metallogenesis of Canadian Uranium Deposits: A Review. Geology, Mining and Extractive Processing of Uranium, Jones, M.J. (Ed.), Proceedings of a Symposium, London, January 17-19, 1977. Institute of Mining and Metallurgy, London, (pp. 43-55), 171 pp.(1976)

Canada has uranium ore reserves that are among the largest in the world. These reserves are contained in the three types of deposits: detrital, hydrogenic, and igneous-metamorphic. The igneous-metamorphic type is represented by the Bancroft district of Ontario, where more than 11,000,000 lb (5,000,000 kg) U3O8 has been produced from pegmatites emplaced in granulite-facies metamorphic rocks. The detrital deposits at Elliot Lake, with production in excess of 190,000,000 lb (86,400,000 kg) of U3O8 by 1976, constitute one of the largest uranium ore districts in the world. The Elliot Lake deposits and a similar deposit at Agnew Lake occur in pyritic quartz-pebble conglomerates, which were deposited in paleostream channels. These deposits were derived from uranium-rich granitic rocks located north of the depositional area and concentrated mainly as detrital heavy minerals. Hydrogenic uranium deposits are represented in the Proterozoic of Canada in shales and several epigenetic types. The epigenetic deposits are generally characterized by pitchblende and hematite, and are generally enriched in Ni, Co, Ag, Cu and As. Chemically favorable graphitic and/or calcareous shelf-facies meta-sedimentary strata commonly form the host rocks. The Port Radium and Beaverlodge deposits are 'classical' veins, which exhibit strong structural control. Stratigraphic control appears more important in the recently discovered 'unconformity veins' that occur near the base of the Athabasca Sandstone in Saskatchewan. At the Rabbit, Key and Cluff Lake deposits most of the mineralization occurs in basement rocks within 100 m of the unconformity, but ore is also found within the regolith and overlying orthoquartzites. (Auth)(PAG)

329
McRae, O.M., and P.L. Grubaugh; AEC, Grand Junction Office, Exploration Division, Grand Junction, CO

Geology of Uranium Deposits in the Inter-River Area, Grand and San Juan Counties, Utah. RME-112; 44 pp.(1957, November)

The Inter-River area is a region of 450 square miles at the junction of the Green and Colorado Rivers in southeastern Utah. Commercial uranium deposits are found in two units of the Triassic Chinle formation: the Moss Back or basal member and the "Black Ledge", a middle Chinle sandstone unit. The most important local controls in the deposition of uranium ore are paleostream channels, intraformational scours, carbonaceous material, and jointing within channels and scours. Most ore bodies contain less than 200 tons of ore. Non-commercial uranium deposits have been found in both the Permian Cutler and Triassic Moenkopi formations. During investigations of

the area, selected areas in Mineral Bottom, Mineral Canyon, Taylor Canyon, and Fort Bottom were drilled. (Auth)

330
Moreau, M., and G. Ranchin; French AEC, La Crouzille Division, France; Penarroya Company, Trappes, France

Hydrothermal Changes and Tectonic Controls in the Intergranitic Uranium Vein Deposits in French Central Massif. Colloque Scientifique International (pp. 77-100); AEC-tr-7567; 45 pp.(1973)

The age measurements made both in Vendee and Limousin indicate that there was an interval of several tens of millions of years between the placement of the granite and the deposit of the uranium-bearing vein mineral. In spite of the high geochemical uranium background of the granites with two mica strata encasing them, the location of the uranium-bearing deposits cannot be attributed to magmatic differentiation. The uranium-bearing mineral deposit is located here in lodes or in columns of feldspathic rocks which are more or less micaceous and vacuolar, without any granitic quartz, referred to as episyenites. These rocks are genetically tied to the granite with the two mica layers and their formation is due to postmagmatic phenomena with a hydrothermal character, developed in certain particular zones of the massif; these underwent a rather belated and prolonged evolution. The primary deposit of pitchblende could be due to the abrupt separation of the CO2 [mixture] whose content is high in terms of certain quartzes in the vicinity of the episyenites and in the mineralized lodes. It is probable furthermore that it is this progressive accumulation of the CO2 in the fluids prior to the separation of the mixture which is responsible for the final petrographic evolution of the mineralized episyenites. Two superposed Hercynian tectonic phases explain the pitchblende enrichment found at the intersections of the early Stephanian and the Late Permian directions. (Auth)

331
Mullens, T.E.; USGS, Washington, DC

Geology of the Clay Hills Area, San Juan County, Utah. USGS Bulletin 1087-H; 77 pp.(1960)

The Clay Hills area includes 296 square miles of canyon and plateau country in southwestern San Juan County, Utah. Rocks exposed in the area were mostly deposited in a terrestrial environment and are of Permian, Triassic, Jurassic, and Quaternary ages. The aggregate thickness of these rocks is about 3,900 feet. The primary purpose of this investigation was to appraise the uranium resources of the Clay Hills area. Among the formations exposed in the region, only the lower part of the undifferentiated Chinle Formation and the Shinarump Member contain stream-deposited sandstone containing carbonaceous materials. At all accessible outcrops both rock units were systematically examined for uranium minerals and geologic features favorable for the accumulation of uranium minerals. Uranium ore associated with copper minerals occurs at several places in the Shinarump member in exposures 3 miles north of the Clay Hills area; and uranium ore associated with copper and vanadium minerals occur at the Whirlwind mine in the Shinarump about 200 yards south of the map area in sec. 2, T. 41 S., R. 13 E. No uranium minerals or areas of abnormally high radioactivity were observed in Shinarump exposures within the map area. Sandstone and conglomerate beds in the lower part of the Chinle Formation are known to be uranium-bearing in other areas of the Colorado Plateau, but no uranium minerals or areas of abnormal radioactivity were found in the exposures of the Chinle in the map area. The lack of uranium mineralization in the outcrops of the two most favorable host rocks, the Chinle Formation and Shinarump member, does not preclude the possibility of uranium ore deposits in the area, as concealed deposits may be present. The lack of uranium mineralization does, however, make an appraisal of the uranium potential in these formations difficult. (JMT)

332
Murphy, F.M.; Union Mines Development Corporation, Grand Junction Field Office, Grand Junction, CO

Richardson Basin District, Green River Desert Area, Utah. RMOO-460; 26 pp.(1945, June)

On the basis of geological mapping and sampling, some 1,000 tons of inferred reserves, estimated to average 0.08 percent U3O8 and 0.36 percent V2O5, have been calculated. Ore exposed sufficiently for

mining is practically non-existent. The uranium occurrence is in and adjacent to fault fissures in the Wingate sandstone of the Jurassic system. Ore deposits consist of irregular and discontinuously filled fissures. The ore-shoots, bunches, pockets, and seams of mineralized material are largely the result of deposition in open spaces in favorable places along narrow fissures and only to a smaller extent by replacement of the intervening or adjoining rock. Carnotite coats the walls of fissures, fractures and joints; it fills or partially fills openings apparently formed by the removal of clay pellets in more friable, una..ered sandstone. (PAG)

333
Nestler, R.K., and W.L. Chenoweth; AEC, Grand Junction Operations Office, Production Evaluation Division, Grand Junction, CO

Geology of the Uranium Deposits of the Lukachukai Mountains, Apache County, Arizona. RME-118; 64 pp.(1958, September)

In a study of the comparative importance of sedimentary and tectonic ore controls and in search of data bearing on the origin of the deposits, ten mines in the Lukachukai Mountains, Apache County, Arizona, were examined in detail. All commercial deposits in the area are in the Salt Wash Member of the Morrison Formation of Jurassic age. The ore bodies are elongate and horizontally lenticular in shape and consist of one or more ore pockets surrounded or separated by protore. The composite length of ore bodies consisting of two or more ore pockets separated by subore grade material ranges up to 1,100 feet; individual ore pockets range up to 350 feet in length. Elongation is usually at least three times the width and is parallel to paleostream depositional trends measured in and near the ore bodies. Claystone and/or siltstone units nearly always underlie and frequently overlie the host sandstone units. Ore occurs most frequently in trough-type, cross-stratified sandstone which fills scours and channels in the underlying claystone units. Lithofacies maps and mine mapping show that ore bodies are restricted to areas of rapid lateral color change which in general are also areas of rapid change in the ratio of mudstone to sandstone. Most ore bodies are located on the southwest flank of the Chuska syncline within a broad belt which trends nearly north-south across the southeast end of the Lukachukai Mountains. It is suggested that a set of shear joints served as vertical channelways for the distribution of migrating uraniferous ground water. Location of the ore belt is apparently controlled by the intersection of these shear joints and particularly favorable facies of the Salt Wash Member. (Auth)

334
Nevskii, V.A., N.P. Laverov, and A.E. Tolkunov:

Structural-Geological Features of Uranium Deposits in Collapse Calderas. Soviet Journal of Atomic Energy 40(2):178-184.(1976, August)

Uranium deposits are found in two types of calderas. Mainly volcanic covers with volcanites having a composition from basic to acid contribute to the structure of the calderas of the first type which have a relatively long geological development history. Caldera faults developed in the final state of the volcanism and therefore have a relatively short history. The uranium deposits are situated in the internal part of the calderas. Extrusive domes and subvolcanic formations composed of acid rocks contribute to the structure of the caleras of the second type which are characterized by the shorter geological development history. A ring fault on the edge limits the dome; this fault developed at the very beginning of the volcanic processes and continued to grow until the magmatic activity subsided. Uranium deposits in calderas of this type are situated in the zone of caldera edge fault. The uranium deposits have a close spatial correlation to the magma-carrying channels in the depth, which developed for a long time and were the paths of movement of hydrothermal solutions during the postmagmatic stage. These channels are confined to the structural elements of highest mobility in the calderas. In the calderas of the first type, areas in which the huge tectonic fractures intersected in a zone of hidden faults of the base were the structural elements of highest mobility. In calderas of the second type, these elements were formed by areas in which caldera edge faults were intersected and activated by huge linear tectonic fractures. The distribution of the mineralization in the calderas of the first type depends significantly upon the positions of volcanic rock horizons having appropriate physical and mechanical properties. In calderas of the second type, the uranium mineralization was confined to the young volcanic domes and to the subvolcanic intrusions whose internal structure determines both the distribution and morphology of the ore bodies. The basic source of the ore material of the deposits was formed by deep crustal zones of magma formation rather than by

small foci near the surface under volcanoes. The deep crustal zones of magma formation also supplied the upper magma pockets. The ore-enclosing volcanic rocks are characterized by a paragentic relation to the mineralization. The deposits have a structural relation to the volcanic formations; the structural relation confines the deposits to deep magma-carrying channels which existed for a long time and which recently were converted into ore-supplying systems. (JMT)

335
Olson, J.C., R.F. Marvin, R.L. Parker, and H.H. Mehnert; USGS, Denver, CO

Age and Tectonic Setting of Lower Paleozoic Alkalic and Mafic Rocks, Carbonatites, and Thorium Veins in South-Central Colorado. Journal of Research of the USGS 5(6):673-687.(1977, November)

Thorium-bearing veins, discovered about 1949-1950 in the Powderhorn and Wet Mountains districts, are apparently related to the alkalic complexes. Alkalic rocks of two general ages are known in the Powderhorn district. An older group of syenite plugs or small stocks was intruded into the preexisting Precambrian rocks about 1350-1400 m.y. ago. The younger group, the complex at Iron Hill, is composed of pyroxenite, carbonatite, and other alkalic rocks and was emplaced about 570 m.y. years ago. Three alkalic intrusive complexes in the northern Wet Mountains are the McClure Mountain Complex, the Gem Park Complex, and the syenite complex at the head of Democrat Creek. The McClure Mountain Complex is composed of an older series of mafic and ultramafic rocks. The Gem Park Complex is almost entirely made up of pyroxenite and gabbro. The syenite complex at Democrat Creek consists chiefly of intrusives of quartz syenite and explosion breccias. Several hundred thorium-bearing veins occur in both the Powderhorn and Wet Mountains districts. These veins are typically tabular bodies about 0.1 to 2 meters thick. The veins are composed of quartz, carbonate minerals, potassic feldspar, barite, and iron oxides. A few tenths percent thorium is present in the veins, mainly as thorite. Rare earth elements are present in variable amounts, generally about as abundant as thorium. It is believed that a great majority, if not all, of the thorium veins are associated with the Cambrian or Early Ordovician alkalic intrusions. The veins occur most commonly in fractures and shear zones, and they are found 30 km or more from the alkalic rock complexes. It seems clear that the vein-forming fluids were able to migrate great distances. The thorium-bearing veins therefore, may delineate a system of fractures in the Earth's crust that existed about the time of the alkalic magmatism. (JMT)

336
Page, L.R.(Comp.), H.E. Stocking(Comp.), and H.B. Smith(Comp.); USGS, Washington, DC; AEC, Grand Junction, CO

Contributions to the Geology of Uranium and Thorium by the United States Geological Survey and Atomic Energy Commission for the United Nations International Conference on Peaceful Uses of Atomic Energy, Geneva, Switzerland 1955. USGS Professional Paper 300; 739 pp.(1956)

The technical literature presented in the report is divided into four parts. The natural occurrences and distribution of uranium in all major geologic environments: igneous rocks; veins; terrestrial and marine sedimentary rocks; and petroleum and asphaltites, are presented in part 1. Part 2 summarizes the geology and mineralogy of thorium and describes various thorium-bearing deposits in the United States. Methods and techniques of analytical chemistry used by chemists working on uranium and thorium problems are summarized in part 3. Part 4, Methods of Prospecting for Uranium and Thorium, discusses in detail the varied applications of geology, geophysics, geochemistry, and botany to prospecting for uranium, as well as the various techniques used in radiometric surveying in the air, on the ground, and in drill holes: seismic and electrial testing; drill-hole logging; physical exploration; water sampling; and many other prospecting techniques. (PAG)

Each paper in this report has been input separately.

337
Petrascheck, W.E., E. Erkan, and W. Siegl; Institut fur Geologie und Lagerstattenlehre, Monanuniversitat, Leoben, Austria

Type of Uranium Deposits in the Austrian Alps. Geology, Mining and Extractive Processing of Uranium, Jones, M.J. (Ed.), Proceedings of a Symposium, London, January 17-19, 1977. Institute of Mining and Metallurgy, London, (pp. 71-75), 171 pp.(1976)

The Permian uranium ore deposits in the Eastern Alps are of the sandstone type, but they show some special features as a result of the orogenic environment of their deposition and of posterior transformation. The deposition was conditioned by a post-Hercynian relief of the Alps: the deposits are localized in lagoonal basins, transverse to the Alpine east-west direction; the type of the deposits was originally tabular; the uranium is connected with organic matter. The Alpine orogeny displaced the original sites of sedimentation, so that now they are situated in different tectonic units, and produced folding, schistosity and an elongated shape of the ore layers in the east-west direction. A mineralogical-petrological comparison of the deposits discloses some differences in composition (uraninite, pitchblende, brannerite, thucholite, uranothorianite and sulphides of Fe and of Cu), which are characteristic for variations of sedimentation and metamorphism. The effect of metamorphism is remarkably low; however, it had a certain influence on the fabrics of the ore-bearing schists and therefore on their porosity; the latter controls the formation of secondary uranium minerals and probably also the possibility of extraction processes. The Permian deposits in Austria are comparatively small (several thousand tons U) and of low grade (about 800 ppm U on average), but some do represent economic prospects. (Auth)

338
Pierson, C.T., and Q.D. Singewald; USGS, Washington, DC

Occurrences of Uranium-Bearing Minerals in the Saint Kevin District Lake County, Colorado. USGS Circular 321; 17 pp.(1954)

Two hundred and seventy-one prospect pits, mine dumps, and mine works within the Sugar Loaf and St. Kevin mining districts were tested for radioactivity by the U.S. Geological Survey in 1951. One hundred and twenty-two weak radioactive anomalies were found in the St. Kevin district, and eight slight anomalies were noted in the Sugar Loaf district. Most of the anomalies were found in Precambrian igneous and metamorphic rocks, but some were found in metalliferous veins of Tertiary age. Samples of altered granite or schist contain as much as 0.065 percent uranium, probably in the form of secondary uranium minerals. Samples of vein material contain as much as 0.013 percent uranium, also probably in the form of secondary uranium minerals. At only a few localities has the identity of the uranium-bearing minerals been determined. Torbernite associated with turquoise, malachite, and chrysocolla, occurs as disseminations and fracture coatings in altered granite at the Josie May turquoise mine; metatorbernite is disseminated in granite at the Turquoise Chief mine. Commonly the limonite-stained fractures in the altered granite and schist are radioactive; metatorbernite has been identified at one locality. A uranium-variety of florencite, a hydrous cerium aluminum phosphate, is disseminated in the granite on the dump of a mine just west of the St. Kevin district, and autunite is disseminated in the fine-grained, highly silicified rock in the northeastern part of the St. Kevin district. None of the uranium occurrences is of commercial importance. They are for the most part in nonglaciated terrane, which has been subjected to a very long period of weathering. Chemical leaching within the zone of weathering may have greatly reduced the uranium content of material near the surface, and occurrences of even small quantities of secondary uranium minerals might be related to stronger concentrations of primary minerals at depth. (Auth)(JMT)

339
Power, W.R.; AEC, Grand Junction Operations Office, Salt Lake City Branch, Salt Lake City, UT

Preliminary Report on the Geology and Uranium Deposits of Haiwee Ridge, Inyo County, California. RME-2066; 37 pp.(1958, March)

The Coso formation of Plio-Pleistocene age, consisting of rhyolitic volcanics, fanglomerates, and lake beds, overlies granite unconformably. It records a period of repeated volcanism and faulting on Haiwee Ridge and almost continuous deposition in Owens Valley that began in late Pliocene or early Pleistocene time. It is overlain unconformably by andesites. Recent normal faults cut the andesites. Uranium minerals believed to be hydrothermal in origin are concentrated at the unconformity between the Coso formation and granite where pre-Coso faults intersect the unconformity. They are not high-grade deposits and there is no indication that they extend at depth into the granite. Other uranium minerals are disseminated in fanglomerates near the base of the Coso formation. (Auth)(PAG)

340
Rich, R.A., H.D. Holland, and U. Petersen; Harvard University, Cambridge, MA

Characteristics of Hydrothermal Uranium Deposits.(1977)

Hydrothermal uranium deposits occur in diverse geological environments and in a variety of rock types ranging in age from Precambrian to Tertiary. Virtually all types of igneous, sedimentary, and metamorphic rocks have been found to host hydrothermal uranium mineralization, but in spite of this, some generalizations do seem valid: 1)Most hydrothermal uranium deposits in the United States are found in host rocks of Precambrian, late Mesozoic, or Tertiary age. In the rest of the world, host rocks are predominantly Precambrian and late Paleozoic. 2)Host rocks in most hydrothermal uranium deposits are felsic igneous and metamorphic rocks. The age of the known hydrothermal uranium deposits range from middle Precambrian to late Tertiary. There is an almost complete absence of hydrothermal uranium deposits of Archean age (greater than 2.5 billion years old), and in the United States, the major deposits have late Mesozoic to Tertiary ages. The mineralogy of hydrothermal uranium deposits is generally simple, with pitchblende virtually always being the only important hypogene uranium mineral. Most veins also contain quartz, calcite and small amounts of sulfides, with pyrite and marcasite being particularly common. Hematization of wall rock is characteristic for many hydrothermal uranium deposits throughout the world. (JMT)

341
Rich, R.A., H.D. Holland, and U. Petersen; Harvard University, Cambridge, MA

Hydrothermal Uranium Deposits. Developments in Economic Geology No. 6, Elsevier Scientific Publishing Company, New York, 264 pp.(1977)

"Hydrothermal Uranium Deposits" is divided into two parts; the first part containing six chapters, and the second part containing descriptions of hydrothermal uranium deposits in North America, Australia, Europe, and Africa. Each of the six chapters has been abstracted for the NURE bibliographic data base. (JMT)

342
Ryan, G.R.; Geopeko Limited, Darwin, Northern Territory, Australia

Uranium in Australia. Geology, Mining and Extractive Processing of Uranium, Jones, M.J. (Ed.), Proceedings of a Symposium, London, January 17-19, 1977. Institute of Mining and Metallurgy, London, (pp. 24-42), 171 pp.(1976)

The bulk of uranium deposits in Australia can be classified as vein-type, which includes the massive new discoveries of the Alligator Rivers region in the Northern Territory, with indicated reserves of pitchblende already in excess of 350,000 tons of contained U_3O_8, as well as bodies of lesser size elsewhere in northern Australia and South Australia. Pitchblende is the most common primary mineral, but refractory minerals such as davidite and brannerite predominate in some instances. The ores are found in zones of disruption or shear in metamorphosed Proterozoic rocks, and are generally considered to be of hypogene origin. The source of the uranium is thought to be by desorption of metal from Proterozoic metapelites during anatexis, or from granitic intrusives themselves of possible anatectic origin. Sedimentary uranium is present in the Tertiary of South Australia, where the uranium has been leached from Lower Proterozoic uraniferous inliers. The Carboniferous of central Australia contains sandstone-type deposits that have been subsequently folded and mildly metamorphosed. In Western Australia, and to a lesser extent possibly in central Australia, sedimentary uranium has accumulated in deposits of calcrete that have formed by replacement of valley-fill deposits in fossil Tertiary drainage channels that contain evaporites. Two unique deposits occur: at Mary Kathleen, where pitchblende is present in allanite in a scapolite-diopside-garnet breccia-conglomerate of Middle Proterozoic age; and the Maureen, where uranium-fluorine-molybdenum mineralization is found in Carboniferous basal sandstone. Uraniferous pegmatites are widely distributed, but have yielded no economic deposit of uranium. Proterozoic conglomerates have been extensively tested, but only thorium minerals have so far been discovered. (PAG)

343
Rytuba, J.J.; USGS, Menlo Park, CA

Geology and Ore Deposits of the McDermitt Caldera, Nevada-Oregon. USGS Open-File Report 76-535; 9 pp.(1976)

The McDermitt caldera is a Miocene collapse structure along the Nevada-Oregon border. The

oval-shaped caldera is bounded by arcuate normal faults on the north and south and by rhyolite ring domes on the west. Precollapse ash-flow tuffs exposed within the south caldera rim consist of three cooling units and are peralkaline in composition. Refractive indexes of nonhydrated glasses from basal vitrophyres of the units range from 1.493 to 1.503 and are typical of comendites. Post-collapse intracaldera rocks consist of tuffaceous lake sediments, rhyolite flows and domes, and ash-flow tuffs. Within the caldera are the mercury mines of Bretz, Cordero, McDermitt, Opalite, and Ruja and the Moonlight uranium mine. The mercury mines are adjacent to ring fracture faults, and the uranium mine and other uranium occurrences are located within rhyolite ring domes. Fluid inclusions in quartz indicate a deposition temperature of 340 degrees C for the uranium deposit and 200 degrees C for the mercury deposits. The mercury deposits formed at shallow depth by replacement of lakebed sediments and volcanic rocks. (Auth)

344
Sharp, B.J.; AEC, Division of Raw Materials, Salt Lake Exploration Branch, Salt Lake City, UT

Uranium Occurrence at the Moonlight Mine, Humboldt County, Nevada. RME-2032; 18 pp.(1955, March)

Uranium mineralization occurs along a north-south trending fault which displaces a sequence of volcanic rocks. A Jurassic intrusive (granodiorite) crops out to the north of the Moonlight mine, and is also exposed in the lower workings. The volcanic sequence was presumably extruded upon an old erosion surface of the granodiorite. The main uranium minerals are autunite, torbernite, and possibly gummite, and uraninite. Gangue minerals include iron oxides, pyrite, quartz, fluorite, and clays. Mineralization is continuous throughout the shaft to a depth of 270 feet. Samples from the Moonlight shaft vary from 0.02 to 0.312 percent U3O8. The average grade throughout 200 feet of depth was calculated to 0.14 percent U3O8 at an average width of 2.5 feet. Ore reserves are estimated to be 1900 tons indicated and 5700 tons inferred at the above grade and mining width. (Auth)(PAG)

345
Sharp, B.J., and D.L. Hetland; AEC, Division of Raw Materials, Salt Lake Exploration Branch, Salt Lake City, UT

Preliminary Report on Uranium Occurrence in the Austin Area, Lander County, Nevada. RME-2010; 16 pp.(1954, May)

The mineralized area, about three miles south of Austin, Nevada, is on the southern fringe of the Reese River silver mining district. Uranium occurs in mineralized fracture zones in quartz monzonite intrusive and contact sedimentary rocks. The mineralized zones are usually associated with fine-grained siliceous dikes, vein quartz, and iron oxide staining. Metatorbernite and autunite are the principal uranium minerals in the oxidized zones. Select samples from the area contained as high as six percent U3O8, and an ore pile extracted from underground workings contained an average value of 0.151 percent U3O8. Prospecting should be concentrated on the mineralized zones in the intrusive rocks and adjacent metamorphosed sedimentary rocks. (Auth)(PAG)

346
Sims, P.K.; USGS, Denver, CO

Paragenesis and Structure of Pitchblende-Bearing Veins, Central City District, Gilpin County, Colorado. Economic Geology 51(8):739-756.(1956, December)

Pitchlende occurs locally along early Tertiary gold-, silver-, and sulfide-bearing quartz veins in the Central City district, Colorado, within the Front Range mineral belt. The veins cut a complex mass of Precambrian metamorphic and igneous rocks and early Tertiary intrusive porphyritic rocks. Pitchblende is present in only a few veins. The ore bodies are localized in structurally controlled open spaces along faults. They occur locally along four of the six vein sets of the district, in the form of ore shoots or small lenses and pods that are separated by vein material essentially devoid of uranium. The shoots are small and measure at most a few tens of feet in height and length, and average less than a foot in width; few contain more than 50 tons of ore. Some of the shoots are systematically arranged within the veins but others are erratically distributed. (MLB)

347
Sims, P.K., and G. Phair; USGS, Washington, DC

Geology of the Copper King Mine Area, Prairie Divide, Larimer County, Colorado. TEI-311, Part 1; 54 pp.(1952, December)

The bedrock in the mine area consists predominantly of Precambrian granite with minor migmatite and metasediments-biotite-quartz-plagioclase gneiss, biotite schist, quartzite, amphibolite, amphibole skarn, and biotite skols. The metasediments occur as inclusions that trend northeast in the granite. The Copper King fault, a breccia zone, contains a deposit of pitchblende; the other faults are later than the ore. The two types of mineral deposits in the mine area are massive sulfide and pitchblende deposits and are of widely different mineralogy, age, and origin. The massive sulfide deposits are small and consist of pyrite, sphalerite, chalcopyrite, pyrrhotite, and in places magnetite in amphibole skarn, mica skols, and quartzite. The massive sulfides are pyrometasomatic deposits of Precambrian age. The pitchblende at the Copper King mine is principally in the Copper King vein; a tight, hard breccia zone that cuts through both granite and the massive sulfide deposits. A small part of the pitchblende is in small fractures near the vein and in boxwork pyrite adjacent to the vein; the post-ore faults, close to their intersection with the Copper King vein, contain some radioactive material. The hard pitchblende is intergrown with siderite; other gangue minerals include pyrite, quartz, and finely fragments of the wall rocks. The vein was repeatedly reopened during mineral deposition as shown by several stages of brecciation and recementation by the vein matter. (MLB)

There are several plates included in the report.

348
Smith, C.T.; Union Mines Development Corporation, Grand Junction Field Office, Grand Junction, CO

Uravan District, San Miguel Plateau Area, Colorado. RMO-439; 82 pp.(1946, May)

The purpose of the investigation was to determine the remaining uranium resources of the Uravan District. For this report the Uravan District is subdivided into the Ophir, Club Mesa, Long Park, and East Paradox localities. The few additional workings which do not fall within the limits of these localities are included in a miscellaneous group. The mineralization of the Uravan District occurs in relatively flat and shallow deposits of varying sizes and shapes. Some are larger and more regular than is usual for Morrison Salt Wash ore bodies. Some faults, fractures, folds, and steepening dips occur. The ore often fades out along the strike and dip of the enclosing beds; it may grade into mudstone or alternate ore and mudstone along a diastem. Ore rolls are developed as spur-like protuberances from the bedded material. The rolls commonly cross-cut the bedding extending outward from thin seams of ore following diastems in the sandstone. Carbonaceous material is associated with bedded ores, commonly occurring a few feet above the diastem which contains the bedded ore. A total of 1,342,131 tons of ore of all grades and types is calculated for the Uravan District. The average grades of ore are 0.23 percent U3O8 and 1.33 percent V2O5. (PAG)

Column and calculation sheets are included in this report.

349
Staatz, M.H.; USGS, Federal Center, Denver, CO

Thorium Veins in the United States. Economic Geology 69(4):494-507.(1974, June)

Thorium-bearing veins are the largest known and most easily exploitable potential thorium resource in the United States. Veins of this type are principally of quartz, feldspar, and iron oxides. They are known from at least 13 widely scattered areas: (1) Lemhi Pass, Montana-Idaho; (2) Diamond Creek, Idaho; (3) Hall Mountain, Idaho; (4) Wet Mountain, Colorado; (5) Powderhorn, Colorado; (6) Laughlin Peak, New Mexico; (7) Capitan Mountains, New Mexico; (8) Gold Hill district, New Mexico; (9) Quartzite district, Arizona; (10) Cottonwood area, Arizona; (11) Monroe Canyon, Utah; (12) Mountain Pass, California; and (13) Wausau, Wisconsin. Thorium-bearing veins in the United States are generally similar in size, shape, attitude, mineralogy, and chemical composition. They occur along fractures with several periods of demonstrable movement that cut brittle host rocks, and they are commonly related spatially to alkalic rock complexes and carbonatites. Furthermore, the thorium and rare-earth content of both alkalic rocks and carbonatites is high. The thorium veins are believed to have been formed from fluids derived from a volatile late-stage phase of magma that formed the alkalic rocks. These fluids followed major through-going fractures, but the veins generally occur in small subsidiary fractures. The length of time needed to form these veins probably varied, but in at least some of the veins the period was long enough for vein material to be deposited, fractured by later

movement, and then the fractures filled by new vein material. The fluids were of low viscosity, as indicated both by some of the tight shears they migrated along and the distances that some are from their probable source. Temperature of vein formation was probably low, as suggested by the fine grain size of the veins and by the distance that some of the vein fluids apparently traveled. New thorium deposits are most likely to be found in the vicinity of alkalic rock complexes with individual veins occupying subsidiary fractures near large faults. (JMT)

350
Staatz, M.H., and H.L. Bauer, Jr.; USGS, Washington, DC

Preliminary Examination of the Uranium Prospect at the Spider No. 1 Claim, Honeycomb Hills, Juab County, Utah. TEM-165; 7 pp.(1950, October)

The Honeycomb Hills are an upfaulted block of highly-folded volcanic rocks. Near the base there is an orange tuff at least 20 feet thick. This tuff consists of a matrix of orange-stained, light-gray rhyolitic material, and fragments of a dark brown, coarse-grained mafic rock. A white tuff, above the orange tuff, consists of a rhyolitic matrix containing red and black fine-grained volcanic fragments. Above the white tuff is a fine-grained gray vesicular rhyolite which is glassy and usually ropy. A thick section of gray rhyolite is above the ropy rhyolite. Two uranium minerals were observed; the first consists of canary-yellow radiating non-fluorescent acicular crystals, and is believed to be uranophane; the second consists of flat yellow fluorescent plates, and is thought to be autunite. The minerals may be found by themselves, or may be intimately mixed on the same specimen. The uranium minerals occur chiefly as coatings along miner fractures in the white tuff. In a few places the minerals are in the tuff, especially in the darker fragments. The uranium minerals are distributed unevenly through the tuff. Several float blocks of rhyolite were seen that contained uranium minerals. At pit No. 1 a sample contained 0.17 percent uranium. Three other samples from pit No. 3 contained 0.02, 0.07, and 0.19 percent uranium. Seven samples, ranging in grade from 0.009 percent to 0.053 percent equivalent uranium, were taken. (MLB)

351
Steinhauser, S.R., E.P. Beroni, and R.C. Plair; AEC, Division of Raw Materials, Denver Exploration Branch, Denver, CO

Preliminary Report on Uranium Deposits in the Gulf Coastal Plain, Southern Texas Including a Section on: Radiometric Airborne Survey of Parts of Karnes, Atascosa, and Live Oak Counties, Texas. RME-1068; 43 pp.(1955, November)

Concentrations of secondary uranium minerals have been found in three formations of Tertiary age in the Gulf Coastal Plain area of southern Texas: the Fayette sandstone of the Jackson formation, the Catahoula tuff, and the Oakville sandstone. The uranium minerals occur in tuffaceous sandstones and sandy shales of continental origin, outcropping in a narrow belt paralleling the Gulf Coast and extending from Gonzales County on the northeast to Duval County on the southwest-a strike length of approximately 150 miles. Uranium minerals that have been identified include autunite, meta-autunite, carnotite, uranophane, schoepite, and a uraniferous opaline material. The mineral assemblage varies considerably among different deposits and may include, locally, molybdenum minerals and an unidentified arsenic mineral. The area covered by the airborne survey included western Karnes, southeastern Atascosa, and northern Live Oak Counties. A Piper PA-18, 135 hp aircraft fitted with a scintillation counter logged a total of 80:40 flying hours. A grid type of coverage was maintained at an altitude of approximately 50 feet throughout the project, and distances of 100 feet, 200 feet and 1,000 feet between grid lines were used in various areas. The major portion of the aerial surveying was done over the Fayette sandstone of Eocene age, where most of the uranium deposits occur. Small areas of the Catahoula tuff of Miocene age and the Yegua formation of Eocene age were also surveyed. Twenty-four radioactive anomalies were located in the 197-1/2 square miles surveyed. An airborne isoradiometric map was made by recording all "highs" of 55 or more microamperes. (Auth)(PAG)

352
Surazhskii, D.Ya.

Uranium Ore Systems: Experience with Morphogenetic Grouping. Soviet Journal of Atomic Energy 42(6):503-512.(1977, December)

A systematic approach to the analysis of the natural phenomena involved in the genesis of forms of uranium ore deposits allows eight fundamental types of ore fields to be distinguished. In these eight types, at least 14 morphogenetic types of deposits, 18 types of ore beds, and 20 types of ore bodies are found. Each type arises as a result of a completely definite combination of external-environmental conditions which are characteristic of this type alone. (JMT)

353
Surazhskii, D.Ya

Progress of Uranium Geology in the USSR. Soviet Journal of Atomic Energy 23(1):1157-1161.(1967, July)

The more important theoretical and practical results of research in the field of uranium geology in the Soviet Union through 1967 are detailed briefly in this review. Covered in the article are tectonic epochs of ore-formation, sources of uranium, hypotheses regarding the depth of formation of hydrothermal uranium deposits, newly discovered uranium minerals, hypotheses of pitchblende genesis, mineral compositions of metasomatic uranium deposits, paragenetic associations of uranium deposits, and geochemical studies of the solubility and stability of uranium minerals. (JMT)

354
Taylor, A.O., and J.F. Powers; USGS, Washington, DC

Uranium Occurrences at the Moonlight Mine and Granite Point Claims, Humboldt County, Nevada. TEM-874A; 16 pp.(1955, June)

Uranium minerals at the Moonlight mine occur in a vein in intensely altered Tertiary volcanic rocks. The known uranium mineralization is spotty and erratic, but ore-grade material is present in the vein. Samples of the vein taken along its outcrop and in the mine shaft contain from less than 0.02 percent to 0.40 percent U3O8. The uranium minerals change from autunite at the surface to torbernite, gummite, and pitchblende below the 90-foot level of the shaft. The Granite Point claims are two miles north of the Moonlight mine at the base of a rhyolite cliff. Radioactivity traverses made along the base and slope of the rhyolite cliff indicate that a large part of the rhyolite is abnormally radioactive. Radioactivity ranges from 0.013 to 0.3 mr/hr and averaged 0.10 mr/hr in the vicinity of the claims. A sample taken at the base of the rhyolite cliff, at the point of highest radioactivity contains 0.02 percent U3O8. (Auth)(MLB)

355
Vine, J.D., and G.E. Prichard; USGS, Washington, DC

Uranium in the Poison Basin Area, Carbon County Wyoming. USGS Circular 344; 8 pp.(1955)

In 1953, sandstone containing as much as 3 percent uranium was found in the Browns Park Formation about 6 miles west of Baggs, Carbon County, Wyoming. Uranophane has been identified as the principal uranium mineral in three select samples and Schroeckingerite as the principal uranium mineral in one sample. The uranium occurrences cannot be evaluated because their dimensions and average grade have not been determined. The presence of uranium, however, is significant because it indicates that uranium deposits may be present in the Browns Park Formation and also in underlying formations unconformably overlapped by the Browns Park. The origin of the uranium deposits is uncertain, but meteoric ground water is believed to be the mineralizing solution, and the source of the uranium is thought to be tuffaceous sandstones of Tertiary age. (JMT)

356
Young, R.G., I. Million, and D.M. Hausen; AEC, Grand Junction Operations Office, Production Evaluation Division, Grand Junction, CO

Geology of the Green River Mining District, Emery and Grand Counties, Utah. RME-98(Rev.); 89 pp.(1960, September)

Outcropping rocks in the Green River district in SE Utah include the Entrada sandstone and the Carmel, Curtis, Summerville, and Morrison formations of late Jurassic age, the Cedar Mountain formation of Early Cretaceous age, the Naturita formation of probable Late Cretaceous age in this area, and the Mancos shale of Late Cretaceous age. Uranium is found chiefly in the Salt Wash sandstone member of the Morrison, and the largest deposits occur in a thick sandstone unit near the top of the member in the Tidwell mineral belt near the western edge of the district.

Primary minerals, identified from Salt Wash ore zones, include coffinite, uraninite, montroseite, sphalerite, pyrite, marcasite, chalcopyrite, and clausthalite. Coffinite is the most common uranium mineral. Secondary ore minerals include corvusite, hewettite, tyuyamunite, metatyuyamunite, uranopilite, liebigite, and schroeckingerite. At and near the outcrop, ores are gray to limonitic brown with coatings of secondary minerals; but at depth they become dark gray to black, largely because associated carbonaceous matter is not obscured by weathering products. Origin of this material is not definitely known. Some is definitely plant material while some is asphaltic matter of humic or petroliferous origin. A third type consists of disseminated microscopic carbon, interpreted as a residue of petroleum, a humic hydrosol or a residue of humic acids. Asphaltic material fills cell centers, and commonly surrounds and appears to corrode and replace quartz grains and ore minerals. A review of evidence concerning the origin of this material indicates that it may have been derived in part from woody materials, and in part from petroliferous material, which may be both pre- and post-mineralization. Corrosion of other minerals may not necessarily indicate a later age for the asphalt. Asphaltic material may have been made corrosive by alpha bombardment from uranium minerals which had originally been precipitated by the asphaltic material. Uranium-bearing solutions may have been hydrothermal solutions which originated at depth, rose along fractures until they encountered permeable Salt Wash, and proceeded to move laterally, or they may have been circulating ground waters which transported the uranium from a distant granitic or magmatic source. These solutions moved more freely through those areas of thick permeable Salt Wash, such as that in the Tidwell mineral belt. Where these solutions came in contact with reducing agents such as humic or petroliferous material, precipitation of uranium occurred. The largest deposits occur where favorable belts of Salt Wash coincide with premineralization structures such as the Tidwell nose. Here, permeability is further increased by intense fracturing of the ore horizon. Bleaching of Salt Wash sandstone is believed to be the result of the leaching action of circulating ground waters charged with humic acids, and may be unrelated to mineralizing solutions. (Auth)(PAG)

GENESIS OF DEPOSITS

357
A'bdel-Gawad, A.M., and P.F. Kerr; Columbia University, New York, NY

Urano-Organic Mineral Association. The American Mineralogist 46(3-4):402-419.(1961, March)

The widespread urano-organic association in hydrothermal deposits suggests a hydrothermal source for the original uranium ions of the Colorado Plateau deposits. Liquid hydrocarbons from the San Rafael Swell may be indurated under conditions of elevated temperature in the range of 200 to 300 degrees C. The heated products give infrared curves similar to natural uranium-bearing asphaltites suggesting that the natural material could have been hardened by the action of hydrothermal solutions. Polymerization caused by irradiation is recognized as a possible originating mechanism for materials of high radioactivity. However, indurated asphaltites low in radioactivity are abundant, and their physical condition is better accounted for by the action of heat derived from hydrothermal solutions barren of uranium. Infrared, x-ray, and differential thermal analysis studies of coffinite indicate that the mineral is a uranium silicate without an essential hydroxyl component. Hydrothermal occurrences of coffinite and the temperature of its synthesis suggest a special significance as a temperature indicator. The intimate coffinite-asphaltite association is not conceivable as a product of irradiation; at the same time, the uranium silicate is a likely product of hydrothermal action. (JMT)

358
Barrington, J., and P.F. Kerr; Columbia University, New York, NY

Uranium Mineralization at the Midnite Mine, Spokane, Washington. Economic Geology 56(2):241-258.(1961, March)

The Midnite Mine is located about 35 air miles northwest of Spokane, Washington on the Spokane Indian Reservation. Uranium mineralization occurs in a zone along the contact between the Cretaceous Loon Lake Granite and Precambrian metasediments. The uranium-bearing ore is of primary, moderate temperature, hydrothermal origin. Some of the ore has been converted to secondary oxidized mineralization. The genesis of the ore deposit is thought to have begun with the introduction of hydrothermal fluids along the contacts of the rock types and in related fractures, faults, and shear zones. These solutions may have represented a late magmatic stage of the intrusive Loon Lake Granite. Solution temperatures were at least below 450 degrees C, possibly considerably lower, and the environment somewhat acidic. Pyrite, which is widespread, suggests widespread penetration of the solutions. As the system cooled, marcasite began to be precipitated in place of pyrite. Fine-grained uraninite was probably formed at the same time as were the small amounts of chalcopyrite and sphalerite with the sulfide phase possibly acting as the precipitating agent for the uranium oxide. Colloidal deposition of marcasite and uraninite may have occurred at any temperature below 450 degrees C, but most probably it took place near 300 degrees C. Molybdenite represents a comparatively high temperature mineral phase deposited near the contact where sufficient temperatures may be expected to have been maintained. Arsenopyrite and excess silica accompanied the first formed pyrite. The paragenetic sequence of metallic mineral formation appears to be molybdenite, arsenopyrite, pyrite, marcasite, uraninite, marcasite, coinciding with a decrease in temperature and a possible retarded increase in pH. Argillic alteration in the form of kaolinite and illite preceded uranium deposition with illite forming in the higher temperature region near the contact. Montmorillonite formed during and following the precipitation of uraninite when temperatures were lower and the environment possibly had become slightly alkaline. The large amounts of montmorillonite at and near the contact indicate that low temperature-moderate pH conditions were maintained for a relatively long period of time and this could have been the predominant environment during ore deposition. (JMT)

359
Dahlkamp, F.J.; Uranerzbergbau Gmblt and Company, Bonn, Federal Republic of Germany

Formation and Types of Uranium Deposits, Uranium Resources. AED-Conf-75-769-024; 40 pp.(1975)

A classification system of uranium deposits is put forth in this report. According to the relationship to the host rock, two groups of uranium ore

forming processes can be distinguished: (1) syngenetic and (2) epigenetic. These ore forming processes can further be divided into the mode of origin and then into type of host rock. According to this scheme, there are six economic types of uranium deposits now known: (1) Conglomerates; (2) Sandstones; (3) Vein Type Deposits; (4) Magmatic Vein Deposits; (5) Intramagmatic Mineralization; and (6) Calcretes. Three potential sources of uranium are uraniferous black shale, phosphate and lignite deposits. (JMT)

360
Eargle, D.H., and A.D. Weeks; USGS, Austin, TX; USGS, Washington, DC

Possible Relation Between Hydrogen Sulfide-Bearing Hydrocarbons in Fault-Line Oil Fields and Uranium Deposits in the Southeast Texas Coastal Plain. USGS Professional Paper 424-D, Article 295, (pp. D7-D9), 408 pp.(1961)

Most of the uranium deposits in the southeast Texas coastal plain are slightly up dip from faults upthrown to the east and within a graben area between the Fashing, Hobson, and Falls City faults. The host rocks in these deposits are the alternating nonmarine and shallow-marine tuffaceous rocks in the upper part of the Jackson Group. These sediments were covered until recent geologic time by the nonmarine Catahoula Tuff. The deposition of the ore may have been brought about by a channeling of ground water into the graben-like area where there was a suitable reducing environment for precipitation of uranium. Alteration of the tuffaceous sediments by ground water may have produced heulandite and released alkalis, silica, and several trace elements including uranium. The uranium was redistributed by alkaline ground water and locally precipitated; the reducing conditions being caused by decay of plant fragments or by hydrogen sulfide which was derived from decaying organic matter in the host rocks or as seepage of natural gas in the deeper Edwards Limestone. Because of a number of natural gas and petroleum discoveries in the immediate area of the uranium deposits, the author suggests that hydrogen sulfide indigenous to the oil and gas deposits was the reducing agent that caused the precipitation of the uranium. (JMT)

361
Fischer, R.P.; USGS, Washington, DC

Similarities, Differences, and Some Genetic Problems of the Wyoming and Colorado Plateau Types of Uranium Deposits in Sandstone. Economic Geology 65(7):778-784.(1970, November)

Uranium deposits of the Wyoming roll type and the Colorado Plateau peneconcordant type are the principal domestic resources of uranium. Both types occur in lenticular sandstone beds of continental origin, have a similar suite of elements and minerals, are associated with mildly altered rock, and are thought to have formed by reduction precipitation from ground waters before significant regional deformation. They differ in several respects. The Wyoming deposits are in unlithified sandstone that is only slightly to moderately arkosic. Uranium is the only ore metal in the Wyoming deposits, whereas vanadium or copper is more abundant than uranium in some of the Plateau deposits. The Wyoming deposits are elongate cresent-shaped bodies that extend vertically through, or partly through, a sandstone unit and which are scattered, like widely spaced beads on a string, along miles-long interfaces between oxidized (altered) and unoxidized sandstone, whereas the Plateau deposits are thin tabular layers that are nearly concordant to bedding and which occur as discrete bodies, like raisins in raisin bread, enveloped in rock altered by reduction. The Wyoming ore rolls and interfaces were dynamic, having been pushed downdip by downward-moving oxygen-bearing water that passed through the interfaces and deposited the ore minerals on the reducing side, whereas the Plateau deposits seemingly formed as static bodies, localized by intensive reducing "patches" in a mildly reducing environment. These differences focus attention on genetic problems relating to the Eh of the ore-bearing and altering solutions, the shape and localization of deposits, and the source of the uranium. (Auth)

362
Gabelman, J.W.; Utah International, Inc., San Francisco, CA

Diatreme Feeding of Uranium. Migration of Uranium and Thorium - Exploration Significance,

J.W. Gabelman. The American Association of Petroleum Geologists, Tulsa, Oklahoma, (pp. 30-35), 168 pp.(1977)

Diatreme feeding of mantle volatiles into receptive host formations at tectonically weak centers as a factor in forming productive uranium districts is discussed in this chapter. The highest known abundance of uranium and thorium in alkalic hypabyssal and volcanic rocks differentiated in the mantle shows the concentration of radioelements in the volatile fraction. These observations support the theoretical inference that mantle degassing is a principal means of radioelement transfer to the crust. Another important inference is that the further differentiation product of concentrated volatiles and fluid without magma should contain an even greater concentration of radioelements than the alkalic rocks or certain carbonatites. Such a gas could easily be the preferred diatreme drilling agent. Juvenile gases are usually evidenced at the surface as fumaroles and these are known mostly in volcanic regions. Uranium has been noted in gases from such regions, and gas-formed diatremes are well known in tectonic regions ranging from mobile belts, through taphrogenic block ranges and volcanic piles to the stable interior. The author cites evidence that many igneous-free breccia and collapsed-plug pipes are mineralized with copper or uranium, and many significant uranium districts contain such pipes. These include Laguna and Grants, New Mexico; Temple Mountain and Spanish Valley, Utah; Cameron, Arizona, Browns Hole and Capital Reef, Utah; Galiup, New Mexico; and Grand Canyon, Arizona. Evidence in the form of "circulars" visible on aerial photographs or ERTS images suggests that pipes may be present in many more districts. The author suggests the possibility that metal-laden volatiles fed the uranium and other related metals through collapsed-plug-capped diatremes into the host sandstones for mineralization either directly from the gas or via the agency of encountered water. (JMT)

363
Gabelman, J.W.; Utah International, Inc., San Francisco, CA

Underemphasized Processes of Uranium Mineralization. Migration of Uranium and Thorium - Exploration Significance, J.W. Gabelman. The American Association of Petroleum Geologists, Tulsa, Oklahoma, (pp. 135-136), 168 pp.(1977)

Although uranium is one of the most studied commercial elements, not all of its mineralization processes are accurately known. Exploration usually proceeds by assuming a specific process or mechanism and then searching for conditions that would permit, support, or induce the process. Early and significant success achieved by following the laterogene and multiple migration-accretion interpretations induced emphasis on this model to the point where it now dominates the bulk of exploratioin, yet the sharply declining success suggests that such a model may have outlived its usefulness. Most of the deposits easily identified by these criteria appear to have been found. Current failures resulting from application of the model are not an indication that it is wrong but rather that it is incomplete, and not the only genesis. Other possible processes and mechanisms for uranium deposition, in decreasing temperature of formation, are as follows: 1) Deuteric crystallization of thorium-uranium minerals in late-phase alkalic granites as "porphyry" disseminations, 2) Hydrothermal replacement of late-phase alkalic granites to form "porphyry" replacement disseminations, 3) Crystallization dissemination of thorium-uranium minerals in late-stage alkalic agpaitic and miakitic syenites, 4) Diapiric emplacement or hydrothermal modification of carbonatites, 5) Hydrothermal-vein formation around taphrogenic alkalic volcanic centers, 6) Diatreme feeding of uraniferous mantle volatiles into favorable host systems, 7) Taphrogenic hydrothermal feeding at tectonic intersections into favorable aquifers or permeable lignites, 8) Laterogenesis at the low-intensity end of the orogenic-metamorphic mobilization gradient, 9) Hypogene laterogenesis in geopressurized basins, 10) Mobilization or localization by salt or shale diapirism, 11) Secretion, transport, and fixation of uranium by nature fluid or gaseous hydrocarbons, and 12) Concentration in evaporite basins. (JMT)

364
Gabelman, J.W.; Utah International Inc., San Francisco, CA

Taphrogenic Continental-Margin History. Migration of Uranium and Thorium - Exploration Significance, J.W. Gabelman. The American Association of Petroleum Geologists, Tulsa, Oklahoma, (pp. 115-117), 168 pp.(1977)

Purely taphrogenic continental margins are difficult to locate in that most continental basements appear to be made up of stabilized

orogene roots. The metal deposits remaining in these roots, however, should be of high temperature threshold mobility and independent of much later taphrogeny which usually produces moderate to low temperature mineralization. The effect produced only by taphrogeny on such an old margin would be illustrated where a nonorogenic sedimentary cover intervenes. The northeast coast of Brazil, covered by Cretaceous rocks, or the Red Sea coast, covered by Miocene strata, are examples. In both areas the beds are moderately folded into small domes and basins and deep high angle faults prevail. Metal deposits are directly associated with these faults, or they occur in zones enclosing the faults. Few deposits occupy the faults as veins. All the minerals are of the low temperature type and are readily soluble in fluids typical of the near surface environment. Since feeder structures and structural control are not evident, the deposits are of debatable genesis. Heat delivered through the faults could have mobilized and concentrated elements from the sediments, provided the sediments can be shown to have had an ample supply of metals and an opportunity to deliver them. Also juvenile fluids could have brought the elements from the mantle through feeders not readily evident. In the Red Sea region, mineralization temperatures were moderately high. Base metals sulfosalts, and silver in brines are known to be delivered by volcanogenic exhalation through the seafloor. Uranium occurs in low temperature veins cutting pre-Cretaceous basement not far from the coast. Although the veins are related spatially to a plutonic to hypabyssal alkalic intrusive complex, their epithermal texture suggests closer affiliation to genesis and age to coastal taphrogeny. In coastal Brazil, where mineralization temperatures were much lower, minerals consist of pyrite, galena, barite, primary and secondary uranium minerals, and iron and manganese oxides. The uranium minerals occur mostly in Cretaceous rocks of the taphrogenic Tucano basin, a graben filled with moderately folded strata. The mineral deposits have been commonly attributed to the popular laterogene processes interpreted elsewhere for sandstone deposits, but the sedimentary sequence is particularly barren of uranium and carbonaceous or clay precipitants. There is better evidence for a taphrogenic origin. The basin produces very hot, salty water from below 1,800 meters. Coffinite was identified in a core from 1,800 meters and carnotite locally impregnates the outcrop of the same sandstone on the basin margin. A fracture stockwork near a fault zone contains veinlets of carnotite bordered by manganese oxide, then by hematite in wall zones. (JMT)

365
Gabelman, J.W.; Utah International, Inc., San Francisco, CA

Geochemical Distinction of Uranium Mineralization Processes. Migration of Uranium and Thorium - Exploration Significance, J.W. Gabelman. The American Association of Petroleum Geologists, Tulsa, Oklahoma, (pp. 121-134), 168 pp.(1977)

Extensive thin-section studies of sandstone ores have shown that, as the intensity of either alteration or metallization increases, replacement of cement becomes complete and replacement of detrital grains begins until ore products can constitute locally more than 50 percent of the rock. The extrinsic mineralization suite of sandstone-type uranium ores generally consists of Ca, Fe, Mg, Ti, Ba, Mn, Sr, V, U, and Mo introduced in relatively large quantities, and Zr, Cu, Pb, Co, Ni, Y, and Ce in minor quantities. The general mineralization suite is very similar to the ultramafic suite typical of piercements from the upper mantle or deep crust, and it is definitely atypical of upper continental sial. The absence from, or deficiency in, the suite of the key elements sodium and potassium, which would strengthen the relation to the alkalic mantle piercements believed to carry most of the mantle volatiles, may be attributable to the difficulty of distinguishing these mantle additions from the alkalies of sedimentary arkoses. The reason extrinsic addition does not significantly increase the intrinsic alkali content of arkoses may be the result of the zonal rearrangement of constituents during mineralization. Potash and perhaps soda are actually leached from the orebodies, but are enriched in distinct margins. Significant to speculation concerning the immediate sources for uranium involved in mineralization of sandstone type deposits is the comparison of the entire group of associated elements, rather than just uranium. The family associated with low-temperature, shallow uranium mineralization of sandstones has strong similarities to the family associated with high-temperature thorium-uranium mineralization and to the family associataed with at least the miaskitic carbonatites. This relation suggests that the fluids which produced the uranium mineralization in the sandstone districts may have been taphrogenically introduced from the mantle. It is natural that they should have mixed in route with meteoric or connate ground waters and could have derived some of their uranium content from leaching of the rocks penetrated. (JMT)

366
Gruner, J.W.; University of Minnesota, Minneapolis, MN

Concentration of Uranium in Sediments by Multiple Migration-Accretion. Economic Geology 51(6):495-520.(1956, September)

Leaching agents, such as the bicarbonates of Ca, Mg, and Na, are very common in nature. They are able to form with uranium compounds which yield the apparently very stable U-tricarbonate ion in a solution saturated with CO3. Because most ground waters contain large amounts of CO3 and these bicarbonates, they are considered powerful reagents for the solution of uranium. They could carry the metal, and also vanadium, long distances through almost neutral environments, always along paths or "channels" of least resistance until reducing conditions were met when black ores would result. If, instead of precipitation, the charged solutions regained the surface, the tricarbonate would decompose and the uranium would be precipitated as uranyl minerals only to be redissolved at a later date by the same process. Concentration of large deposits could proceed by several stages of oxidation-solution-migration-accretion. Orogenic movements with resulting new unconformities and new gradients would make more uranium available and add to the large number of depositional variations encountered. (Auth)(PAG)

367
Guilinger, R.R.; Union Carbide Corporation, Globe Mining Company, Riverton, WY

Source of Uranium in the Gas Hills Area, Wyoming. Economic Geology 58:285-286.(1963)

In a drilling, a highly radioactive piece of rock in a five foot ore run of core taken 237 to 242 feet from the surface was found at the Dick no. 17 claim owned by Globe Mining Company in the Gas Hills Area, Wyoming. The rock measured 3 in. X 2 in X 1 in. and was surrounded by unconsolidated coarse arkosic material which normally makes up the ore in the area. The rock was analyzed and found to contain veinlets of uraninite. The matrix of the rock was identified in thin section as a highly altered quartz diorite or granodiorite containing major amounts of slightly to moderately sericitized andesine plagioclase feldspar and quartz with virtually no mafic minerals present. The rock fragment is inferred to be a previously existing primary uranium vein deposit that originated in the Precambrian rocks of the Granite Mountains. The author suggests that uranium in the Gas Hills deposits was originally derived from these hydrothermal veins and later deposited in the permeable sandstone channel deposits in the Wind River Formation by reduction of the uranium by hydrogen sulfide formed from bacteriologic processes. (JMT)

368
Katayama, N.

Genesis of Uranium Deposits in Sedimentary Rocks. International Geological Congress, Proceedings of a Conference, Copenhagen, Denmark, 1960. Part 15, Genetic Problems of Uranium and Thorium Deposits, (pp. 7-14), 164 pp.(1960)

Most uranium deposits are found in terrestrial sediments. Their features in the unoxidized zone implies that they were deposited from stagnant, reducing ground water. The concentration of uranium in ground water is 10(E-7) to 10(E-6) g/l in terrains of moderate climate, while it rises to 10(E-7) to 10(E-3) g/l in arid terrestrial basins as well as in uranium deposits. This indicates that the origin of uranium in terrestrial sediments, at least of young age, is supergene. The difference between the features of younger and older deposits of this type can be explained by the reworking subsequent to the primary deposition of uranium. (Auth)

369
Kovalev, V.P., A.D. Nozhkin, A.G. Mironov, and Z.V. Malyasova;

Redistribution and Mobility of Uranium During the Metamorphism of Volcanogenic Formations. Soviet Journal of Atomic Energy 41(2):697-703.(1977, February)

Effusive and intrusive petrochemical analogs differ considerably in regards to their content of ordinary and mobile uranium. This is because of the fundamentally differing conditions of solidification of the chemically identical melts. As products of rapid supercooling of aluminosilicate melts, effusives mechanically capture all the uranium dissipated within them, and as a result of the metastable state of the main mass fail to transfer this uranium to solutions without the complete chemical decomposition of the material composing them. The initial concentration and

distribution of the uranium in volcanogenic rocks are altered when epigenetic processes associated with tectonic magmatism and metamorphism develop on the large scale. As they develop regional, local, contact, and hydrothermal forms of metamorphism lead to the appearance of different amounts of mobile uranium and to a change in the original content. Ultrametamorphism leads to the greatest loss of uranium. The most promising sites for the discovery of uranium ore formations are regions of acid volcanism having widely evident areas of low- and medium-temperature hydrothermal metamorphism, with traces of later tectono-magmatic activization. No less favorable are regions corresponding to the propagation of early volcanogenic accumulations of the same composition which have experienced metamorphism of the greenschist facies and then been subjected to hydrothermal action. The uranium contained in volcanogenic rocks can only migrate after fundamental recrystallization of the rock-forming material, or after its complete decomposition, which may be effected either in metamorphic processes or alternatively in exogenic processes in which chemical decomposition of the rocks takes place. Effusive-explosive formations usually undergo the greatest metamorphic transformations in the epigenetic stage of their existence, by virtue of the appearance of a superimposed deep tectono-magmatism influencing and basically modifying the volcanogenic strata. (JMT)

370

Langford, F.F.; University of Saskatchewan, Department of Geological Sciences, Saskatoon, Saskatchewan, Canada

A Supergene Origin for Vein-Type Uranium Ores in the Light of the Western Australian Calcrete-Carnotite Deposits. Economic Geology 69(4):516-526.(1974, June)

The discovery of a major uranium deposit in the calcretes of Western Australia confirms the economic importance of this type of occurrence. The calcrete is a surficial limestone formed by near-surface groundwater; uranium derived by weathering of nearby granite occurs as carnotite in vugs and fractures in the calcrete. Vanadium has been important in fixing uranium as insoluble carnotite and appears to have been derived from the surrounding laterites. Since the calcretes are unequivocally of surficial and recent origin, the uranium must have been similarily formed. The genetic importance of such surficial processes to the origin of sedimentary deposits of the Colorado type is easily visualized. However, a surficial origin for uranium in pitchblende-vein deposits also satisfactorily explains their spatial and temporal relationships to unconformities and uranium-rich granitic complexes. Vein deposits in the Northern Australia uranium province are good illustrations of the features attributed to surficial sources of uranium in pitchblende-vein deposits. (Auth)

371

Maslyn, R.M.; Colorado School of Mines, Golden, CO

An Epigenetic Model for the Formation of the Schwartzwalder Uranium Deposit. Economic Geology 73(4):552-557.(1978, June)

The Schwartzwalder uranium deposit is located along Ralston Creek, 8 miles north of Golden, Colorado. Over nine million pounds of U3O8 have been produced from the mine, making it one of the largest non-sandstone uranium deposits in the United States. Mine workings follow a series of northwest trending fissures related to the Laramide-age Rogers fault system. Mineralization, consisting of pitchblende with minor amounts of coffinite in an ankerite, calcite, pyrite, chalcopyrite gangue, is found as open space fillings in both the fissures and fault breccias. Individual ore zones reach up to 35 feet in width. The mineralization tends to be discontinuous along the fissures, particularly in the upper portions of the mine. This discontinuous nature of the mineralization reflects the tendency for the areas of major mineralization to occur in either the garnetiferous biotite gneiss or phyllitic schist units in the host metamorphic rocks. Since the uranium occurs in veins with a vertical continuity of over 1,500 feet in Precambrian rock, the Schwartzwalder has been classed as a typical hydrothermal vein uranium deposit. Several characteristics of the deposit, however, raise questions concerning the likelihood of such a hydrothermal origin. The author proposes an epigenetic model for the deposit, suggesting the source of the uranium was the nearby Denver Formation; a tuffaceous silty claystone, tuffaceous arkose, and andesitic conglomerate. Detritus stripped from the rising Front Range highland accumulated as the Arapahoe and Denver Formations in the Late Cretaceous and Early Tertiary. Streams depositing these units followed generally southeastward courses across the

highland. Water flowing in the Ralston Creek paleovalley carried quantities of uranium leached from the volcanic tuffs. This water carrying the uranium in solution traveled through the sediments supplying the uranium to the open fractures in the Precambrian metamorphic rocks underlying the valley. As the uraniferous surface water traveled downward in the open fissures, it mixed with hot spring waters carrying H2S in solution, rising along the nearby Rogers fault into the fissures. The H2S reduced the uranium in solution, which then deposited in available open spaces in the fissures and fault breccia. (JMT)

372
McGrew, P.O.; University of Wyoming, Department of Geology, Laramie, WY

The Tertiary History of Wyoming. Wyoming Tectonics and Their Economic Significance, A.R. Renfro (Ed.), Proceedings of the Twenty-Third Congress, Casper, Wyoming, September 20-22, 1971. Wyoming Geological Association, Casper, (pp. 29-33), 187 pp.(1971)

During the Late Cretaceous, much of Wyoming was submerged by a transgressing sea. When the sea retreated at the end of the Cretaceous, an almost featureless plain was left. Shortly following, several mountain ranges began to appear, most notably, the Granite Mountains, and by the beginning of the Tertiary most of the major structural features presently seen were outlined in western and southern Wyoming. Deposition in the low lands continued in most basins without a break. Coal swamps occurred in great abundance. During the Paleocene epoch, several basins formed, in which spread rather large lakes. The best known of these lakes is the Waltman Lake in the Wind River Basin, in which 1500 feet of dark shales were deposited. Other lakes appear to have formed at this time in the Big Piney-LaBarge area and probably in the vicinity of Hiawatha. The Eocene history of Wyoming was probably the most complex of all the Tertiary. By the very early Eocene, most of the structural features that characterize Wyoming today were fully developed. Structural unrest at this time produced many thrusts and folds. Many of the mountains were rejuvenated and eroded supplying conglomerates and arkoses to the basin margins. The Wind River and Granite Mountains were thrust to the south and southwest, and great fans of coarse arkose spread from the Granite Mountain. It is in the arkoses that several of Wyoming's most valuable uranium deposits are found - Shirley Basin, Gas Hills, Crooks Gap, and possibly the southern Powder River Basin. Throughout the Paleocene and Eocene, eastern Wyoming and the plains were apparently going through a period of exposure. Oligocene rocks in eastern Wyoming lie on deeply weathered Cretaceous sediments suggesting a long period of weathering prior to the beginning of the Oligocene. Sediments for the first time spilled over the mountains and onto the plains. Around the mountains are locally derived conglomerates and sands, but most Oligocene sediments consist of a white, gray, or pink clay, derived from ash blown from the Absaroka-Yellowstone volcanic centers. It has been suggested that these Oligocene rocks were the source of Wyoming's uranium deposits. Miocene and Pliocene rocks are poorly represented in Wyoming due to erosion and during the Pleistocene, there was little but erosion, re-excavating the mountains and washing much of the Tertiary sediment onto the plains of Nebraska and South Dakota. (JMT)

373
Nash, J.T.; Columbia University, New York, NY; USGS, Menlo Park, CA

Uranium Deposits in the Jackpile Sandstone, New Mexico. Economic Geology 63:737-750.(1968)

The Jackpile Sandstone is an arkosic, highly feldspathic sandstone that was derived from granitic, volcanic, sedimentary, and possibly metamorphic rocks. It is a local unit, forming the uppermost section of the Jurassic Morrison Formation. Near Laguna, New Mexico, major uranium deposits occur in the Jackpile. Field and laboratory studies indicate that an organic environment is a critical feature of ore deposition, the major precipitant having been introduced epigenetically and probably derived from decaying vegetable matter. A combination of reduction and sorption probably prevailed to produce high enrichment, followed by formation of colloidal coffinite. Structural controls to ore are not apparent, but sedimentary permeability had an important effect on the distribution of organic decomposition products and ore. Stratigraphic and textural features, along with lead-uranium ages indicate that the ore was emplaced while the host sandstone was near the surface during the pre-Dakota hiatus. Either of two sources for the uranium appear most likely prior to the Dakota; fluids from Morrison volcanoes, or labile constituents in the Jackpile Sandstone. The preservation of delicate volcanic debris and

City district, the magmatic enrichment in both uranium and thorium reached a peak of more than 20 fold over the best available averages for granitic rocks. The sequence of events in the Central City district is thought to be as follows: (1) intrusion of slightly to moderately radioactive monzonite throughout the eastern half of the district, (2) intrusion of excessively radioactive, nonporphyritic varieties of quartz bostonite in the western half of the district north of what was to become the area of pitchblende deposition, (3) intrusion of the highly radioactive quartz bostonite porphyry dikes with which 15 of the 17 known occurrences of pitchblende are now associated (within 500 feet), (4) deposition of pitchblende as a local and unusual variant in the regional pyritic-gold ore deposition near, but not in, the quartz bostonite porphyry dikes. The implication of the field and chemical evidence is that uranium-rich solutions given off by a cooling quartz bostonite mass at depth became further enriched by leaching uranium from the quartz bostonite channelways while en route to higher levels. Zircon, the probable host for much of the uranium and part of the thorium in the rocks, separated in reduced amounts from the youngest quartz bostonite liquids--a change which, in effect, tended to throw uranium into the residual liquid. Possible mechanisms by which uranium became concentrated with respect to thorium in the derived aqueous solutions are considered. In this connection the late magmatic introduction of fluorite and of ferric oxides may be of special significance. (Auth)

377
Phair, G., and F.G. Fisher; USGS, Washington, DC

Potassic Feldspathization and Thorium Deposition in the Wet Mountains, Colorado. USGS Professional Paper 424-D, Article 293, (pp. D1-D2), 408 pp.(1961)

Thorium is rare as a hypogene constituent in hydrothermal veins, and the few hydrothermal deposits so far discovered appear to be the result of special processes. In this paper, a working hypothesis is presented relating thorium deposition in the Wet Mountains to potassic feldspathization of granite along weathered, oxidized fractures beneath an impervious cap of volcanic rocks. Breccia zones cut a wide variety of igneous and metamorphic rocks, but large high-grade thorium deposits are developed only in granite. Such granite has undergone intensive and extensive feldspathization, resulting in vuggy aggregates of coarse- to fine-grained red potassic feldspar containing less than 4 percent albite. During potassic feldspathization of the granite, large quantities of SiO2, MgO, CaO, Na2O, and BaO were dissolved into the altering solutions and incorporated into the principal gangue minerals (quartz, barite, dolomite, and calcite) of fissure fillings. Elements in which the feldspathized aggregates are enriched (Fe+3, Al, Th, Y, and locally Nd, Ce, La, Be, and Nb) are those normally concentrated in granite and syenite during magmatic differentiation. Because part of the feldspathization involved a simple replacement of K^+ for Na^+ in the feldspar lattice, with the associated Al^{+3} remaining behind, the altering solutions developed a considerable excess of Na2O over that which could react with Al2O3 to form albite. Thorium minerals belong to a late stage in complex paragenetic sequence, and are believed to represent a reconcentration from the enriched protore. Such short-range transport as may have occurred is tentatively attributed to carbonate complexing in solutions of appropriate alkalinity. The early-formed breccia zones served as conduits for ground waters and became deeply oxidized in their uppermost portions prior to the onset of vulcanism. Once these conduits were capped by impervious volcanic rock, the "trapped" groundwaters heated by the regional rise in the geotherms lay in contact with partly weathered silicate rocks for an appreciable length of time and acquired a relatively high pH. The high pH in turn set in motion the process of potassic feldspathization, and secretion of thorium and formation of the enriched protore resulted from this process. To an unknown extent the alkaline waters may have been augmented by (a) surface waters which took on a high pH as they seeped downward through the partly glassy volcanic cover, and (b) hydrothermal solutions, presumably of higher temperature but lower pH, coming from below. Scattered lead-zinc deposits are inferred to have been formed from hydrothermal solutions under more strongly reducing conditions and at greater depth than the thorium ores, but as part of a more or less continuous process. Such acid, reducing solutions rising to higher zones, would become "buffered" at a higher pH by the ubiquitous iron hydroxides there concentrated and eventually would become indistinguishable from the "trapped liquid". (JMT)

378
Rich, R.A., H.D. Holland, and U. Petersen; Harvard University, Cambridge, MA

euhedral quartz bipyramids suggest that volcanism continued through Morrison time and may have been near the deposit area. Fluid emanations from these Morrison volcanoes may have carried uranium upward through structures such as the Woodrow pipe. A more likely source for uranium is in the sediments altered prior to the Dakota. Petrographic studies indicate that the originally arkosic sands were reduced in most places to subarkose or orthoquartzite before or shortly after sedimentation. Traces of uranium present in feldspars, heavy minerals, and volcanic debris which were destroyed prior to the Dakota would have been available for concentration. (Auth)(JMT)

374
Nininger, R.D., D.L. Everhart, H.H. Adler, and J. Kratchman; AEC, Washington, DC

The Genesis of Uranium Deposits. International Geological Congress, Proceedings of a Conference, Copenhagen, Denmark, 1960. Part 15, Genetic Problems of Uranium and Thorium Deposits, (pp. 40-50), 164 pp.(1960)

The fluviatile or basin environment common to the large number of important uranium deposits in continental sedimentary rocks, the ubiquity of fossil plant material, and the bacterial origin of the sulfide as indicated by sulfur-isotope ratios represent strong evidence for ground water as the emplacing vehicle for these deposits and against deposition directly from purely hydrothermal solutions of magmatic origin. Ground water as an ore solution has been dominant in the trend of geologic thought regarding uranium deposition but there has persisted a tendency to consider magmatic sources relatively near known deposits. Fracture system studies have failed to prove that fractures served as conduits for uraniferous magmatic solutions. Leaching of granitic rocks has been suggested as the source of uranium in a large number of deposits in continental sandstones. In other areas a possible granitic source is more remote and of uncertain location. Leaching of uranium from uranium-bearing tuffaceous sediments is also consistent with field evidence in many localities. There has also been adequate igneous activity in some areas at the proper time to have introduced uranium into the ground-water system; in other areas uranium could have been derived from hypogene sources at relatively shallow depths for which there is no evidence at the surface. (PAG)

375
Page, L.R.; USGS, Washington, DC

The Source of Uranium in Ore Deposits. International Geological Congress, Proceedings of a Conference, Copenhagen, Denmark, 1960. Part 15, Genetic Problems of Uranium and Thorium Deposits, (pp. 149-164), 164 pp.(1960)

The two hypotheses as to the origin of uranium deposits are (1) the leaching of uranium from detrital or igneous rocks by normal ground waters and (2) the escape of uranium from granitic or alkalic magmas as late, residual fluids. Few, if any, deposits can be attributed to the leaching of normal detrital or igneous rocks, but many are the result of redistribution of uranium from ore deposits, or concentrations previously formed from hypogene solutions. It is indicated that in many places these hypogene solutions start escaping magmas long before the formation of granite and continue, perhaps intermittently, until the end of fractional crystallization. There seems to be evidence for the escape of uraniferous solutions from the magma at about the same time that diabase and lamprophyre dikes were intruded. Uranium escaping from the more acid members of magmatic sequences seems to be less important volumetrically. The spatial relation of epigenetic uranium deposits to various types of igneous intrusive bodies and to major structural elements strongly suggests that the source of uranium in most districts is at considerable depth. The metal associations in the deposits can be explained only by such an assumption. Surface waters are effective only in leaching and redistributing the hypogene uranium and its associated metals in certain types of deposits, such as those of the Colorado Plateau or the upper parts of veins in arid climates. (Auth)

376
Phair, G.; USGS, Washington, DC

Radioactive Tertiary Porphyries in the Central City District, Colorado, and Their Bearing Upon Pitchblende Deposition. TEI-247; 53 pp.(1952, August)

Results of analyses of 117 samples indicated that the Tertiary porphyry sequence in the middle part of the Front Range ranks among the most radioactive igneous series in the world. With the intrusion of nonporphyritic, lime-poor, quartz bostonite dikes in the western half of the Central

The Deposition of Pitchblende from Hydrothermal Fluids. Hydrothermal Uranium Deposits, R.A. Rich, et al., Elsevier Scientific Publishing Company, New York, (pp. 52-63), 264 pp.(1977)

The classic explanation for the formation of sandstone-type uranium deposits also seems the best explanation for the formation of many hydrothermal uranium deposits. The presence of hematite as a vein and wall rock mineral in most hydrothermal uranium deposits is consistent with uranium transport in the hexavalent valence state. The deposition of sulfides and arsenides with or shortly after pitchblende is consistent with the reduction of hexavalent uranium to tetravalent uranium and the deposition of the very sparing soluble UO2 at low fO2. The isotopic composition of sulfur in sulfides and of carbon in carbonates observed in some hydrothermal uranium deposits, as well as the frequent localization of ore in the vicinity of reducing wall rocks, is consistent with, and probably best explained by, the reduction-deposition model. The presence of rather large CO2 concentrations in fluid inclusions from some hydrothermal uranium deposits suggests that CO2 may be important for uranium transport, but the effect of CO2 loss on UO2 deposition is unclear. There are too few systematic data to define the effect of pH on the solubility of pitchblende at elevated temperatures and the effect of pH changes on the development of hydrothermal uranium deposits, but it seems likely that the effects of changes in solution pH are not as important as those of redox reactions. (JMT)

379
Rich, R.A., H.D. Holland, and U. Petersen; Harvard University, Cambridge, MA

Origin of Hydrothermal Uranium Deposits. Hydrothermal Uranium Deposits, R.A. Rich, et. al., Elsevier Scientific Publishing Company, New York, (pp. 64-76), 264 pp.(1977)

Three models for the origin and formation of hydrothermal uranium deposits are discussed. The supergene model proposes shallow leaching of uranium by oxidizing surface waters, followed by pitchblende precipitation at depth, as the mode of origin. The deep meteoric water model suggests that the uranium is leached by deeply circulating oxidizing waters of surface origin, with pitchblende deposition occuring as reducing conditions are encountered. The non-meteoric water model proposes that the uranium is leached by deeply circulating oxidizing waters which are not of direct surface origin (e.g. magmatic, metamorphic, and sedimentary formation waters), followed by pitchblende deposition. The presence of red beds in the right hydrologic position is required for the third model and would be extremely important in the second. Many important hydrothermal uranium deposits occur in crystalline basement rocks associated with, or overlain by, either red bed or clean sandstone units (e.g. the Beaverlodge district, Schwartzwaslder mine, Rabbit Lake mine, Great Bear district, and Cluff Lake deposit). Paleogeographic reconstructions suggest that other important hydrothermal uranium districts, such as the Erzgebirge, Pribram, and the Massif Central may also have been overlain by continental red beds at the time of uranium mineralization. (JMT)

380
Rich, R.A., H.D. Holland, and U. Petersen; Harvard University, Cambridge, MA

Review of Fluid Inclusion Studies of Hydrothermal Uranium Deposits. Hydrothermal Uranium Deposits, R.A. Rich, et. al., Elsevier Scientific Publishing Company, New York, (pp. 23-34), 264 pp.(1977)

With one exception, all of the filling temperatures for the pitchblende stages of the hydrothermal uranium deposits discussed in this paper are less than 190 degrees C; with most of the deposits having filling temperatures less than 150 degrees C. Although filling temperatures, in general, are lower than formation temperatures, the epithermal nature of many hydrothermal uranium deposits and the low (less than 1 kb) formation pressures suggest that the formation temperatures were not markedly higher than the filling temperatures. The absence of daughter crystals in most fluid inclusions of the pitchblende stage suggest that the fluids depositing pitchblende have low to moderate salinities. The carbon dioxide content of the pitchblende stage fluids in generally less than 1 mole percent. In total, fluid inclusion studies of hydrothermal uranium deposits suggest that pitchblende is usually deposited at low to intermediate temperatures and pressures from carbon dioxide bearing, aqueous fluids of low salinity. (JMT)

381
Rosholt, J.N., Prijana, and D.C. Noble; USGS, Denver, CO

Mobility of Uranium and Thorium in Glassy and Crystallized Silicic Volcanic Rocks. Economic Geology 66(7):1061-1069.(1971, November)

Analyses of hydrated and nonhydrated glass pairs from three welded ash-flow units and four lava flows of Tertiary age from the Western United States show that the uranium and thorium contents of hydrated glass, when corrected for water hydration, are nearly identical to those of the parent nonhydrated glass. The uranium content of nine crystallized specimens, however, is only 20 to 70 percent of that in the glasses from the same unit. These differences reflect a loss of uranium from the crystallized material by some combination of (a) distillation as the volatile fluoride during cooling and crystallization and (b) ground water leaching after cooling. The thorium content of primarily crystallized groundmass material is nearly the same as that in glasses from the same unit. The possibility appears remote that volcanic ash layers that have undergone hydration without devitrification have provided a large source of uranium in ore deposits in stratigraphically underlying sediments, such as in the intermountain basins in Wyoming. Comparison of the potential source of uranium available from granites in this area suggests that approximately 20 grams per 1,000 kilograms of granitic rock may have been available, whereas a maximum of 5 grams uranium per 1,000 kilograms of original volcanic material could have been available in the volcanic ash devitrified. (Auth)

The longitude and latitude for the sample locality listed in Colorado is actually in New Mexico, and is probably a misprint.

382
Roslyi, A.I.

***Concentration of Uranium Ores in* Carbonate Rocks.** Lithology and Mineral Resources 10(1):67-76.(1975, November)

As determined by detailed studies of a layered epigenetic ore deposit in the carbonate oil-water horizon, origin of uranium ores is closely associated with intrusion of reducing solutions enriched in iron and several other components. Ore mineralization was accompanied by a contrasting reduction and pyritization of layer-by-layer oxidized limonitized rocks. It was preceded by leaching, argillization, recrystallization, and hematitization of these rocks. Distribution of uranium ores was controlled by faults and to a lesser extent by the intercalations of permeable stylolitic limestones. The ore deposits are grouped into fault-associated, layer fracture-associated, and roll-shaped. (Auth)

383
Roubault, M., and R. Coppens; Centre de Recherches Radiogeologiques de Nancy, Nancy, France

Migration of Uranium in Crystalline Rocks and the Possible Relation of This Phenomenon to the Genesis of Certain Deposits. Peaceful Uses of Atomic Energy, Proceedings of the 2nd International Conference, Geneva, September 1-13, 1958. United Nations, Vol. 2, Survey of Raw Material Sources, (pp. 335-337), 843 pp.(1958)

Systematic studies of radioactivity of several granites and the process by which the uranium migrates were made to determine the relation between this migration and the genesis of certain uranium deposits. From the studies, it appears that the migrations of uranium are related to the alterations of granites, and, at least to some extent, this implies that water served as a vehicle for the hexavalent uranium ions. The process of the migration follows the following steps. (1) Biotite and other iron-bearing minerals are oxidized initiating the appearance of iron in the Fe+2 form. (2) Oxidation and destruction of certain radioactive inclusions result in the liberation of uranium. (3) The hexavalent uranium ions are reduced to the tetravalent state by the Fe+2 and then adsorped by the oxides of iron which form in the absence of sulfur ions. (4) The uranium remains temporarily in the altered minerals or escapes through the fissures. (5) Phosphorus may appear as the result of destruction of the phosphates (apatite, xenotime, monazite, etc.), sometimes transforming the uranium concentration into autunite. (6) If the uranium content of the granite is high (exceeding 10 ppm) the excess may be the result of enrichment made possible from the suggested process. The presence of autunite in a granite does not necessarily imply the existence of a uraniferous deposit in the vicinity. The mineral could have been formed

directly from leaching of altered granitic massifs. Conversely, a uraniferous deposit, particularly of the vein type, is not necessarily the result of long distance transport by hydrothermal solutions from a deep-seated source. It may be the result of concentration in place of a short migration of uranium normally disseminated through the granite massifs and mobilized by the process outline. (JMT)

384
Seeland, D.A.; USGS, Washington, DC

Eocene Fluvial Drainage Patterns and Their Implications for Uranium and Hydrocarbon Exploration in the Wind River Basin, Wyoming. USGS Bulletin 1446; 21 pp.(1978)

The source of the uranium-bearing solutions that formed the ore deposits near the Granite Mountains is not known, but the uranium may have been leached from post-Wind River tuffaceous rocks of Oligocene and Miocene age, from granitic rocks of Precambrian age in the core of the Granite Mountains, or from arkosic sandstones of early Eocene age derived from the Granite Mountains. A Granite Mountains source for the host rock and the presence of fluvial-channel sandstone bodies of the Wind River Formation are apparently important factors in the localization of the Gas Hills, Shirley Basin, and Crooks Gap uranium deposits. Based on these two factors, paleocurrent maps derived from the study of fluvial crossbedding of the Wind River Formation in the Wind River Basin of central Wyoming were used to identify two areas having a maximum probability of uranium mineralization. An additional factor favoring uranium precipitation is the possibility that gas containing such reductants leaked into the sandstone from adjacent gas fields, such as the Waltman field, which underlies the paleo-Wind River channel-sandstone bodies. The moving-average paleocurrent map of the Wind River Formation clearly shows the source areas for the lower Eocene rocks of the basin and locates the area in which channel-sandstone bodies of the paleo-Wind River in Paleocene time is quite probably similar to that of the river in Eocene time, based on limited paleocurrent data from the margin of the basin. Oil and gas accumulations in the channel sandstones of the Eocene and Paleocene paleo-Wind Rivers are more likely where they overlie the organic-rich Waltman Shale Member in central and northeastern Wind River Basin. (JMT)

385
Sokolova, N.T., and B.N. Acheyev; Vernadskiy Institute of Geochemistry and Analytical Chemistry, Academy of the USSR, Moscow, USSR

Causes of Localization of Uranium Mineralization in Contact-Metamorphism Aureoles of Granitoids. Geochemistry International 9(6):1067-1077.(1972)

Contact metasomatism associated with granitoids plays a role in the localization of hydrothermal uranium mineralization. Hydrothermal uranium mineralization occurs in the contacts of major granite intrusions only in areas where the intrusions are in contact with greatly altered sediments and volcanics of mainly basic series; areas of contact with the monotonic phyllites have practically no uranium mineralization. Contact metamorphism has produced mainly extensive mineral changes; the most extensive change in the basic rocks is that they have lost virtually all of their CO2. The basic series is rich in Ca, Mg, and Fe, which react vigorously with the CO2 in the uraniferous hydrothermal solutions, leading to the deposition of the uranium. This reaction is much less important for the acid series. Other things being equal, contact metamorphism is important to the localization of hydrothermal uranium mineralization, its main role being extensive geochemical preparation of the country rock. (JMT)

386
Spirakis, C.S., M.B. Goldhaber, and R.L. Reynolds; USGS, Denver, CO

Thermoluminescence of Sand Grains Around a South Texas Roll-Type Deposit. USGS Open-File Report 77-640; 13 pp.(1977)

The thermoluminescence of quartz and feldspar grains around a south Texas roll-type deposit was studied to determine whether a systematic variation in such thermoluminescence exists. Measurements of the thermoluminescence were made in the temperature ranges of 100 degrees to 322 degrees C and 315 degrees to 410 degrees C. Neither temperature range yielded data to differentiate between oxidized and reduced rock. The ratio of the lower temperature to the higher temperature thermoluminescence, however, was consistently higher in ore and reduced rock than in oxidized rock. Studies of thermoluminescence may be useful in identifying alteration related to uranium mineralization. (Auth)

387
Stuckless, J.S., and I.T. Nkomo; USGS, Denver, CO

Uranium-Lead Isotope Systematics in Uraniferous Alkali-Rich Granites from the Granite Mountains, Wyoming: Implications for Uranium Source Rocks. Economic Geology 73(3):427-441.(1978, May)

Twenty-three samples selected from 200 surface and core samples were analyzed by gamma-ray spectrometry for Ra equivalent U, Th, and K. The uranium content of the samples ranged from 0.36 ppm to 1459 ppm. Whole rock Th-Pb, whole rock Rb-Sr, and zircon U-Pb ages are concordant at 2,600 m.y., but the whole rock Pb-Pb age is distinctly older. The apparent age is attributed to a 10 to 45 percent uranium loss between 1,400 and 1,700 m.y. ago, when the granite was subjected to an ill-defined metamorpic event. A second and more extensive uranium loss occurred after the granites were exposed to near surface conditions by the Laramide orogeny. This loss has left the whole rock U-Pb ages variable and generally impossibly old. Granites that exhibit the largest recent uranium loss are characterized by high silica, thorium, and alkali contents and moderate biotite contents. These features suggest that the uranium content of the granites was much greater than it is today because of a 70 percent or greater loss of uranium in recent times. Hence, present day uranium contents may not be a good indicator of favorable granitic source rocks. A few thin zones of uranium reconcentration were analyzed and found to contain 20 to 1,460 ppm uranium. The only feature common to these samples appears to be intense fracturing. This fracturing appears to be an important control in the forming of ore deposits in granites. (JMT)

388
Tugarinov, A.I., and V.B. Naumov; V.I. Vernadskiy Institute of Geochemistry and Analytical Chemistry, Academy of Sciences, Moscow, USSR

Thermobaric Conditions of Formation of Hydrothermal Uranium Deposits.
Geochemistry International 6(1):89-103.(1969)

Pressures and temperatures of the formation of hydrothermal uranium deposits were determined by the methods of homogenization and decrepitation of gaseous-liquid inclusions. It was established that the pressures during the formation of the deposits can substantially exceed the value of the lithostatic load of the overlying rocks. Ore stages of uranium deposits may form in a wide temperature range - at least from 350 degrees to 50 degrees C, however, different forms of uranium compounds correspond to different temperatures. At temperatures above 250 degrees C, uranium mineralization is represented by uraninite or brannerite. In all the deposits studied in which the chief ore mineral was the pitchblende variety of uraninite, the ore stages did not exceed 200-220 degrees C. (Auth)(JMT)

389
Warren, C.G.; USGS, Denver, CO; Colorado State University, Fort Collins, CO

A Method for Discriminating Between Biogenic and Chemical Origins of the Ore-Stage Pyrite in a Roll-Type Uranium Deposit. Economic Geology 66(6):919-928.(1971, September)

Some roll-type uranium deposits are marginal to an altered tongue in sandstone beds that originally contained more-or-less uniformly distributed pyrite. Mineralizing solutions percolated through the sandstone, oxidized nearly all the pre-existing pyrite, and then redeposited part of the pyrite downstream in an embryonic ore zone. The pyrite and the entire ore zone continued to migrate downstream in the sandstone, much as a sand dune migrates. The amount of pyrite in mature deposits varies systematically with the position in the ore body. It is postulated that the rate at which the pyrite was redeposited controlled the systematic variation in distribution of pyrite. Biogene and chemical models which are described in the literature provide alternate explanations for the genesis of roll-type uranium deposits in sandstone. The different theoretical rates for the precipitation of pyrite in the two genetic models provide a distinctive distribution of pyrite that characterizes each process. The theoretical difference between the biogenic and chemical models provides a mathematical technique for identifying the origin of a deposit. Mathematical analysis of the pyrite content of a uranium deposit in the Shirley Basin, Wyoming, illustrates a practical application of the theory. Although a definite conclusion about the origin of roll-type deposits would require considerably more data than are now available, the pyrite content of this deposit does correspond to the theoretical pyrite content of the chemical model, suggesting that a disproportionation reaction was involved in its formation. (Auth)

URANIUM INDUSTRY

390
Bendix Field Engineering Corporation, Grand Junction Operations, Grand Junction, CO

Survey of Lands Held for Uranium Exploration, Development and Production in Fourteen Western States in the Six Month Period Ending June 30, 1975. GJO-109(76-1); 23 pp.(1975, December)

Tabulated data are presented on land distribution by ownership, distribution by states, distribution by land category, and land control by county and state. Data were derived from public county records of mining claim locations, from the public reports of state and federal land offices, from commercial reporting services, and from annual reports to stockholders of land companies. (PAG)

391
Arnold, E.C., O.J. Anderson, D.A. Donaldson, R.W. Foster, K.S. Hatton, J.M. Hill, F.E. Kottlowski, and G.B. Page; New Mexico Institute of Mining and Technology, New Mexico Bureau of Mines and Mineral Resources, Socorro, NM

New Mexico's Energy Resources '76 - Annual Report of Office of the State Geologist. New Mexico Bureau of Mines and Mineral Resources Circular 148; 27 pp.(1977)

New Mexico's energy resources, petroleum, natural gas, coal, uranium, and geothermal, are discussed. In uranium production, New Mexico is first among all the states, with over 5,500 tons of U_3O_8 being extracted for 2,985,000 tons of ore in 1975. During that same year, over 49 percent of the total work force in the uranium mining and milling industry in the United States were employed in New Mexico. The total footage drilled for uranium in New Mexico in 1975 was 5,698,000 feet; 22 percent of the national total. Exploration drilling in search of new ore deposits or extensions to known deposits was 65 percent of the total, while the remaining 35 percent was accounted for as development drilling. (JMT)

392
Becherkin, S.G., V.G. Bakhurov, and I.K. Lutsenko

Underground Leaching of Uranium from Low-Grade In Situ Ores. Soviet Journal of Atomic Energy 24(1):154-159.(1968, January)

In comparison with orthodox systems of mining ores, underground leaching eliminates the costly processes of mining-out the ore, additional crushing and comminution, and storage of radioactive tailings and also improves the output per man-shift and general working conditions. Underground extraction of uranium requires certain preparatory mining operations. The ore is fractured in blocks of 30 to 60 meters in height. The heaped ore is sprayed by means of pumps and a set of atomizers, ensuring that the whole surface is wetted. The solvent used is sulfuric acid solution. The procedure developed for processing the ore was based on intermittent spraying. The solutions are passed through the whole layer of ore, collected in a special sump beneath the block, passed to a tank installed in the lower level, and then pumped to the surface for further processing. Uranium is extracted from the working solutions by an extraction-sorption process, and the solutions were then used for further leaching. During underground leaching, uranium is converted from the coarse ore to the soluble form at the usual mine temperature of 10 to 12 degrees C. The mechanism of such leaching is similar to that of so-called capillary leaching, in which the solution of the reagent does not occupy the spaces between the ore fragments, but merely covers them with a film. The possibility of migration of the radioactive elements during underground leaching was tested and found to be negligible and localized short distances from the mined blocks. (JMT)

393
Corner, J., and G.P. De Beer; Atomic Energy Board, Geology Division, Pelindaba, Pretoria, Republic of South Africa; Atomic Energy Board, Isotopes and Radiation Division, Pelindaba, Pretoria, Republic of South Africa

The Use of Radiometric-Logging Techniques to Determine Uranium Grade in Certain Mineralized Karoo Boreholes. PEL-252; 13 pp.(1976, May)

Twenty-two mineralized boreholes in nine different Karoo uranium occurrences were logged radiometrically with the aim of determining to what accuracy the actual uranium grade could be predicted from the gamma logs. The true uranium

grades of the mineralized zones logged were known from existing chemical analyses. The results showed that the uranium grades could be predicted to an accuracy of better than 10 percent through the use of gamma-logging equipment calibrated at Pelindaba, provided that the ore was in equilibrium and that little or no thorium was present. Disequilibrium is, however, prevalent in the Karoo, and in the holes logged it occurred by depletion of uranium relative to its gamma-emitting daughter products. Such effects were mostly confined to the zone above the water table, and it is concluded that for Karoo-type occurrences, the high radiometric background levels observed over extended distances in some boreholes were indicative of radon-gas buildup, and hence of disequilibrium. It is further concluded that radiometric borehole logging can largely replace chemical analyses in the determination of uranium grade for ore-reserve calculations, although chemical checks for disequilibrium would always be necessary. (Auth)

394
Davis, J.F.; Rocky Mountain Energy Company, Denver, CO

Review of the Uranium Industry in the USA. Geology, Mining and Extractive Processing of Uranium, Jones, M.J. (Ed.), Proceedings of a Symposium, London, January 17-19, 1977. Institute of Mining and Metallurgy, London, (pp. 109-112), 171 pp.(1976)

The 145,000 MWe of nuclear capacity that will be operational in the USA by 1985 will demand an annual production of U3O8 of 39,000 tons (the 1976 figure is 17,000 tons). The short-term pressures on the uranium industry to expand mining and milling capacity and the long-term pressures to discover more uranium and to increase basic reserves are therefore readily apparent. Milling capacity, for example, must grow from 28,000 tons of ore per day at present to 145,000 tons per day by 1985. In the face of these estimated requirements it is clear that changes in traditional exploration, mining and milling methods must take place. Current and possible future developments in exploration, mining and processing in the USA are outlined, as are the effects of increasingly important political and environmental considerations. The governmental program, which is designed to provide industry with the data and technology needed for exploration and mining and to assess American uranium resources is discussed. (Auth)

395
Derry, R., K.H. Garrett, N.W. Le Roux, and S.E. Smith; Warren Spring Laboratory, Department of Industry, Stevenage, Hertfordshire, England; Ministry of Defence, Aldermaston, Berkshire, England

Bacterially Assisted Plant Process for Leaching Uranium Ores. Geology, Mining and Extractive Processing of Uranium, Jones, M.J. (Ed.), Proceedings of Symposium, London, January 17-19, 1977. Institute of Mining and Metallurgy, London, (pp. 56-62), 171 pp.(1976)

The development of a process for uranium extraction in which beds of ore are leached with bacterially regenerated lixiviant is described. The process has been examined at pilot scale and extractions of 95 percent were obtained from ore containing 0.12 percent U3O8. In the process a series of submerged beds of -3 mm ore was leached continuously for up to 10 days at 50 degrees C and pH 1.2. The uranium was recovered by ion exchange and the ferrous solution regenerated by the action of THIOBACILLUS FERROOXIDANS at 30 degrees C. The overall acid consumption was lower than that used in conventional sulphuric acid leaching. Economic analysis shows cost savings of around $2/kg ($0.90/lb) (1971 prices) as compared with the conventional process, largely because grinding is minimized and a separate solid-liquid separation step is avoided. (Auth)

396
Gant, O.J., Jr.; Southern Methodist University, Geology Department, Dallas, TX

Theory and Application of Uranium Ore Grade Determination by Gamma Ray Self Absorption in Layered Media. Ph.D. Thesis; 153 pp.(1975)

The results of theoretical and experimental investigations on a method of gamma-ray logging in which uranium ore grade is determined by self-absorption of the gamma-ray flux is described. The self-absorption technique is examined and methods of interpreting complex layers are discussed. The numerical model applied to solve the complex layer problem was developed

grades of the mineralized zones logged were known from existing chemical analyses. The results showed that the uranium grades could be predicted to an accuracy of better than 10 percent through the use of gamma-logging equipment calibrated at Pelindaba, provided that the ore was in equilibrium and that little or no thorium was present. Disequilibrium is, however, prevalent in the Karoo, and in the holes logged it occurred by depletion of uranium relative to its gamma-emitting daughter products. Such effects were mostly confined to the zone above the water table, and it is concluded that for Karoo-type occurrences, the high radiometric background levels observed over extended distances in some boreholes were indicative of radon-gas buildup, and hence of disequilibrium. It is further concluded that radiometric borehole logging can largely replace chemical analyses in the determination of uranium grade for ore-reserve calculations, although chemical checks for disequilibrium would always be necessary. (Auth)

394
Davis, J.F.; Rocky Mountain Energy Company, Denver, CO

Review of the Uranium Industry in the USA. Geology, Mining and Extractive Processing of Uranium, Jones, M.J. (Ed.), Proceedings of a Symposium, London, January 17-19, 1977. Institute of Mining and Metallurgy, London, (pp. 109-112), 171 pp.(1976)

The 145,000 MWe of nuclear capacity that will be operational in the USA by 1985 will demand an annual production of U3O8 of 39,000 tons (the 1976 figure is 17,000 tons). The short-term pressures on the uranium industry to expand mining and milling capacity and the long-term pressures to discover more uranium and to increase basic reserves are therefore readily apparent. Milling capacity, for example, must grow from 28,000 tons of ore per day at present to 145,000 tons per day by 1985. In the face of these estimated requirements it is clear that changes in traditional exploration, mining and milling methods must take place. Current and possible future developments in exploration, mining and processing in the USA are outlined, as are the effects of increasingly important political and environmental considerations. The governmental program, which is designed to provide industry with the data and technology needed for exploration and mining and to assess American uranium resources is discussed. (Auth)

395
Derry, R., K.H. Garrett, N.W. Le Roux, and S.E. Smith; Warren Spring Laboratory, Department of Industry, Stevenage, Hertfordshire, England; Ministry of Defence, Aldermaston, Berkshire, England

Bacterially Assisted Plant Process for Leaching Uranium Ores. Geology, Mining and Extractive Processing of Uranium, Jones, M.J. (Ed.), Proceedings of Symposium, London, January 17-19, 1977. Institute of Mining and Metallurgy, London, (pp. 56-62), 171 pp.(1976)

The development of a process for uranium extraction in which beds of ore are leached with bacterially regenerated lixiviant is described. The process has been examined at pilot scale and extractions of 95 percent were obtained from ore containing 0.12 percent U3O8. In the process a series of submerged beds of -3 mm ore was leached continuously for up to 10 days at 50 degrees C and pH 1.2. The uranium was recovered by ion exchange and the ferrous solution regenerated by the action of THIOBACILLUS FERROOXIDANS at 30 degrees C. The overall acid consumption was lower than that used in conventional sulphuric acid leaching. Economic analysis shows cost savings of around $2/kg ($0.90/lb) (1971 prices) as compared with the conventional process, largely because grinding is minimized and a separate solid-liquid separation step is avoided. (Auth)

396
Gant, O.J., Jr.; Southern Methodist University, Geology Department, Dallas, TX

Theory and Application of Uranium Ore Grade Determination by Gamma Ray Self Absorption in Layered Media. Ph.D. Thesis; 153 pp.(1975)

The results of theoretical and experimental investigations on a method of gamma-ray logging in which uranium ore grade is determined by self-absorption of the gamma-ray flux is described. The self-absorption technique is examined and methods of interpreting complex layers are discussed. The numerical model applied to solve the complex layer problem was developed

for three active layers and the solution of the resulting system of linear equations is described. (JMT)

397
Gomez Jaen, J.P., J.M. Josa, J.R. Membrillera, J. Otero, and J.R. Serrano; Empresa Nacional del Uranio, S.A., Madrid, Spain; Junta de Energia Nuclear, Madrid, Spain

Mining and Processing of Uranium Deposits in Salamanca, Spain. Geology, Mining and Extractive Processing of Uranium, Jones, M.J. (Ed.), Proceedings of a Symposium, London, January 17-19, 1977. Institute of Mining and Metallurgy, London, (pp. 103-108), 171 pp.(1976)

Based upon geological and processing studies the Junta de Energia Nuclear began to mine uranium in the province of Salamanca, Spain. The orebody, FE-1, is composed of slate of Cambrian age and the fissures are filled by primary minerals. Secondary minerals are impregnated in the zone affected by the hydrostatic level. The orebody is of the stockwork type in which carbonaceous matter has acted as a reducing agent. The average grade of the ore is 0.09 percent U3O8 at a cutoff grade of 0.02 percent U3O8; the deposit is therefore among the lowest-grade deposits that are currently mined. Annual production is 1,200,000 tons of rock, of which 200,000 tons is ore-bearing. The milling plant uses a static heap-leaching method, followed by solvent extraction (tertiary amines) and precipitation by ammonia. Studies have led to the introduction of modifications that have increased the production capacity from 75 to 112 tons U3O8 per annum with no significant alteration in the initial planned investment. The total recovery after processing is 75 percent of the U3O8 contained in the ore. (Auth)(PAG)

398
Gubkin, N.V., D.T. Desyatnikov, and I.K. Rudneva

Advantages of Mining Uranium in Inudated Sheet Deposits by Underground Leaching. Soviet Journal of Atomic Energy 24(1):633-636.(1968, January)

The method of working uranium deposits by underground leaching entails feeding chemical reagents down boreholes where the uranium is dissolved and pumped out in solution. The extracted solutions are then fed to sorption columns resulting in an end product of uranium concentrate which can be processed. The essential advantages of this method of uranium mining is that it allows deposits that could not normally be mined profitably by conventional methods to be worked, it is cheaper than conventional underground mining, and it uses groundwater, which often hinders other types of mining operations. The idea behind the method is to consider the bed as a natural percolator. The formation of sheet infiltration uranium deposits is due to the fact that the useful component was fed by groundwaters to a water-permeable bed and deposited by oxidizing-reducing conditions. If artificially produced opposing geochemical conditions can ensure the water will run through the ore-bearing bed, the uranium from the ore will enter solution and move with it via the permeable rocks. By knowing the lithology and morphology of the ore-bearing beds the movement of the solutions can be controlled. Economic calculations show that the outlay on operating many deposits by conventional mining methods would be at least double that for underground leaching. (JMT)

399
Jackson, D.D.; University of California, Lawrence Livermore Laboratory, Livermore, CA

Chattanooga Shale: Uranium Recovery by IN SITU Processing. UCID-17479; 47 pp.(1977, April 25)

The Chattanooga and related Devonian shales cover extensive areas in the eastern and central United States. These shales contain only about 60 ppm uranium, but if a low-cost extraction method is developed, they would greatly augment domestic uranium reserves. In addition to uranium, these shales also have a relatively high content of organic material with a recoverable oil content averaging 8 gal/ton (39 cubic meters/Gg). The recovery of uranium by IN SITU leaching of the shales has been studied for about 20 years. The process involves extracting oxidized uranium from a relatively permeable host rock. The problem in applying such methods to the Chattanooga shale is that it is an impermeable, reducing formation, which would require additional processing in order to provide the necessary permeability and oxidation state. Such conditions might be produced by a three-stage sequential recovery process entailing (1) fracturing, (2) retorting, and (3) pressure leaching. The fracturing step could be accomplished either by hydraulic or explosive fracturing. After

fracturing, the shale must be retorted by igniting the rubble and injecting air or oxygen to support combustion and force the burn front evenly forward. As the burn front advances, the organic material in the shale, kerogen, decomposes to yield shale oil, gas, and carbonaceous residue. Acid pressure leaching or pressure leaching with carbonate solutions are two possible methods of extracting the uranium. Environmental aspects of these processes will have to be carefully studied before actual exploitation of the uranium resources in the Chattanooga Shale can begin. (JMT)

400
Jones, M.J. (Ed.); The Institute of Mining and Metallurgy, London, England; Commission of the European Communities, Brussels, Belgium

Geology, Mining and Extractive Processing of Uranium. Proceedings of a Symposium, London, January 17-19, 1977. Institute of Mining and Metallurgy, London; 171 pp.(1977)

The symposium presented most aspects of discovering, mining and upgrading uranium ore, and drew attention to the problems of ensuring supplies of nuclear energy raw materials at acceptable prices, with reference to the Western European scene. Nineteen papers were presented and were divided as follows: 2-economic aspects, 6-mining and extractive processing of uranium ores, and 11-geology, prospecting, and discussion of uranium deposits. (PAG)

Papers presented at the symposium have been abstracted and input separately.

401
Keleghan, W.T.H.

Whims for Low Grade Uranium. Nuclear Active 16:3-5.(1977, January)

Wet high-intensity magnetic separation (WHIMS) is a technique used for the removal of weakly magnetic minerals from slurries. It is presently being tested by the Ore-dressing Division of the National Institute for Metallurgy (NIM) in cooperation with the Extraction Metallurgy Division of the Atomic Energy Board and the Nuclear Fuels Corporation of South Africa in an attempt to recover the substantial quantities of uranium in the tailings dams along the Witwatersrand and in the Orange Free State gold mines. Results from the tests indicate that up to 50 percent of the gold and up to 70 percent of uranium can be recovered by the WHIMS method. (JMT)

402
Lackey, J.A.

Solution Mining (IN SITU Leaching) - A Literature Survey. Amdel Bulletin 19:40-61.(1975, April)

IN SITU leaching has been applied to the recovery of copper, uranium, and evaporites. Such operations can be divided into the following types: unfractured orebodies, fractured orebodies, and stope leaching. Solution mining from unfractured orebodies consists of inflow and outflow bore-holes. Because of solution recovery and other associated problems, certain criteria have to be met for solution mining to be successful. These are that the mineral values should occur in a generally horizontal bed underlain by a relatively impermeable stratum, the ore must occur below the static water table, and the direction and velocity of the regional water must be known. In addition, chemical precipitation in the orebody should not be allowed to occur. Fracturing of orebodies can be accomplished by hydraulic means, by chemical or nuclear blasting or by ore subsidence due to conventional mining in adjacent areas. Solution mining operations using hydraulic fracturing techniques probably face the same restrictions as operations on unfractured orebodies. Solution recovery from the other types of fractures should not present the same problem as for unfractured ore or hydraulically-fractured ore operations. Similarly, chemical precipitation in the ore is probably only a problem with unfractured or hydraulically-fractured ore. Chemical and nuclear blasting of orebodies are probably only economically viable for breaking of large tonnages of ore. Because of safety problems associated with the blast, these operations cannot be located near population centers. Dump leaching technology is also applicable to IN SITU leaching of ore broken by blasting and subsidence. Solution recovery from IN SITU leaching of subsided ores and stope leaching is simplified by collecting in shafts, tunnels, and slopes below the area being leached. (JMT)

403
Leist, N.R.; National Lead Company of Ohio, Cincinnati, OH

The Beneficiation and Refining of Uranium Concentrates. New Mexico State Bureau of Mines and Mineral Resources Circular 118; Selected Papers from 1970 Uranium Symposium at Socorro, New Mexico, R.J. Roman and D.H. Baker, Jr. Compilers, (pp. 29-44), 61 pp.(1971)

The tributyl phosphate (TBP) liquid extraction process used for the purification of uranium concentrates at the National Lead Company of Ohio has been drastically modified during the past two decades. The present high-productivity flowsheet employed for the purification of domestic concentrates is described in this paper. Although the modified TBP system has a greater tolerance for the impurities in concentrates, some maximum impurity limits must be specified. The purification capabilities of the modified system are discussed in terms of the impurities normally found in various types of concentrates. (Auth)

404
Lutsenko, I.K., V.G. Bakhurov, and R.S. Meshcherskaya

Physical and Chemical Process Conditions for Underground Uranium Ore Leaching. Soviet Journal of Atomic Energy 27(1):1291-1295.(1969, July)

Uranium transfer from ore to reagent solution consists of direct interaction between mineral surfaces and the leaching agent filtering through an ore layer, and the diffusion transfer of salts into an immobile pore solution, given a concentration gradient. The kinetics of capillary ore leaching in underground workings are determined by interdiffusion between leaching agent and uranium-bearing solution. Process duration and completeness of uranium extraction depends on ore porosity, structure, physical and mechanical properties, nature of uranium mineralization, and contact surface areas with leaching agent. Given appropriate ore preparation the capillary leaching method might be applied to underground uranium leaching from low grade oxidized ore having distinct porosity. Dense ores with an effective porosity 0.7-2.0 percent need to be broken to less than 60 mm when ore is won in the mine working. This allows the attainment of uranium extraction of 51-62.1 percent into a sulfuric acid solution. More porous rocks with effective porosity of 2.0 percent and more may be broken to less than 100 mm. In this case uranium extraction into solution would range from 61.3 to 81.0 percent, depending on porosity. (JMT)

405
Mautz, E.W.; National Lead Company of Ohio, Cincinnati, OH

Production of Uranium Tetrafluoride and Uranium Metal. New Mexico State Bureau of Mines and Mineral Resources Circular 118; Selected Papers from 1970 Uranium Symposium at Socorro, New Mexico. R.J. Roman and D.H. Baker, Jr., Compilers, (pp. 45-54), 61 pp.(1971)

Manufacturing techniques for uranium tetrafluoride production and uranium metal production at the National Lead Company of Ohio are given. The historical background of uranium production is also presented. (PAG)

406
Merino, J.L., and J.M. Josa; Junta de Energia Nuclear, Madrid, Spain

Study of Spanish Uraniferous Sandstones. Geology, Mining and Extractive Processing of Uranium, Jones, M.J. (Ed.), Proceedings of a Symposium, London, January 17-19, 1977. Institute of Mining and Metallurgy, London, (pp. 63-70), 171 pp.(1976)

Uraniferous sandstones from the Mazarete region of Guadalajara contain approximately 0.1 percent U_3O_8 and are of medium hardness. Results are presented of investigations into the following: grinding and thickening, leaching (conventional and heap leaching), countercurrent decantation and slurry characteristics, solvent extraction and precipitation, and effluent neutralization and radioactive decontamination. Leaching with dilute acid gives a high uranium recovery with a low acid consumption. High solids pulp plus strong acid leaching does not increase the uranium recovery, but the CCD results are better than those obtainable conventionally. The ore has a high content of clayey fines, and decantation and thickening of the tailings are difficult. The addition of flocculant and the use of high unit areas are necessary. Overflows are not very clear and underflows have low solids concentration. (PAG)

407
Michel, P.; COGEMA, Fontanay-aux-Roses, France

Methods de Lixiviation sans Broyage Prealable dans le Traitement des Minerail d'Uranium. Geology, Mining and Extractive Processing of Uranium, Jones, M.J. (Ed.), Proceedings of a Symposium, London, January 17-19, 1977. Institute of Mining and Metallurgy, London, (pp. 13-19), 171 pp.(1977)

Heap leaching of uranium ores that have not been subjected to any mechanical preparation has been done in a simple manner, primarily on marginal or lean ores, necessarily extracted in the normal course of mining and quarrying. This ore is treated on water-tight waste areas. The method can be applied to some slightly richer ores, after crushing, on recoverable areas as additional cheap production. A variation of this process, accelerated leaching in vats or on recoverable areas, could be a principal means of production for ores of average grade from deposits with limited reserves. It may then be possible to obtain uranium concentrates at competitive prices. IN-SITU leaching, originally used to exhaust mined areas by treating existing workings with reagents and recovering the leach liquors, has been extended to operations that include a limited amount of mining (mixed method). IN-SITU leaching does not imply preliminary mining operations except for the drilling of holes to inject and recover the solutions and, eventually, the breaking up of the exploitation area. IN-SITU leaching is only applicable provided that the problems associated with isolation of the deposit from the hydrological network have been resolved (risk of pollution or flooding), and that reagents can be brought into contact with mineralized zones. (PAG)

408
Nevskii, B.V., and V.G. Bakhurov

Basic Principles for Underground Metal Leaching Process in Permeable Bedded Ore Deposits. Soviet Journal of Atomic Energy 27(1):1285-1290.(1969, July)

There are four basic requirements for an underground leaching system. The first is to maintain the solution flow rate through the ore bed at maximum stable level by selecting a leaching agent which would guarantee minimum irreversible colmatage of the bed, and by using surface-active additives to increase the permeability. Raising the coefficient of diffusion is the second requirement. This is accomplished by raising the temperature and lowering the viscosity of the solution, by increasing the flow rate, and by using wetting agents. The third requirement is to maintain the maximum concentration gradient at the interface so to maintain the maximum concentration of metal in the pore solution. This requires creation of favorable conditions for raising the rate of chemical reaction. Control of the rate and direction of leaching-solution flow in the ore bearing bed that would guarantee the adequate flushing of all its sections is the fourth requirement. This is attained by locating boreholes having taken into account the areal distribution of the metal and the relief of the underlying impermeable bed, by working out the optimum regime of solution injection and extraction, and by choosing the distance between boreholes having taken the morphology of the ore body into consideration. (JMT)

409
Sadykov, R.Kh.

Temperature Dependence of Diffusional Recovery of Uranium from Clay Strata. Soviet Journal of Atomic Energy 43(3):823.(1978, March)

A method of successive extraction was used to study the effect of temperature on the kinetics of leaching uranium from clay rocks. Sulfuric acid solution (20 g/liter) was used for the leaching. The uranium content in the clay was 0.132 percent, the moisture content of the clay was 30 percent by weight, and the density of a dry sample was 1.5 g/cubic centimeters. Experiments were carried out at 8, 20, 40, 60, and 80 degrees C. It was established that the amount of metal leached from the rock is directly proportional to the duration of the process. Diffusion coefficients for uranium under the experimental conditions varied regularly from 0.0095 cubic centimeters/day to 0.035 cubic centimeters/day. The rate of leaching of uranium from the clay beds was estimated using one of the partial solutions of the Fick diffusion equation. A linear relation between log k and 1/T was found. This suggest the possibility of using the relation $k=A \exp(-Q/RT)$ to describe the temperature dependence of the kinetics of the leaching of uranium from clay beds (k is the diffusion coefficient; A is a constant equal to k when T is approaching infinity; Q is the activation energy; R is the universal gas constant; T is the temperature in degrees K). Graphical

calculation gives a value of 3.5 kcal/mole for the activation energy under the experimental conditions. The value is only valid for the given experimental conditions and it may be assumed that the relative variation in the temperature dependence is the same for other conditions. (JMT)

410
S'elton, R.L., and P.A. Scowen; Head Wrightson Process Engineering Limited, Stockton-on Tees, Cleveland, England

Improvements in Processes and Equipment for the Uranium Industry and Their Effect on Plant Costs. Geology, Mining and Extractive Processing of Uranium, Jones, M.J. (Ed.), Proceedings of a Symposium, London, January 17-19, 1977. Institute of Mining and Metallurgy, London, (pp. 140-144), 171 pp.(1976)

Various processes have been reported that utilize strong acids to leach uranium ores. The United Kingdom Atomic Energy Authority has carried out extensive testwork and has patented a process. Plant requirements for strong acid leaching are discussed and areas of potential cost savings highlighted. A new design of mixer-settler, the "low-profile" mixer-settler, is discussed and potential cost savings are emphasized. Laboratory-scale test results of the strong acid leaching process are given for various ore types. The extraction of the maximum percentage of uranium is discussed in relation to optimum conditions of curing time, temperature, ore particle size and use of oxidant. Capital and operating costs for various plant sections are compared for dilute and strong acid processes. (Auth)

411
Smith, G.W.; Sandia Laboratories, Optoelectronics Division 2542, Albuquerque, NM

Status Report on the Development of a Prompt Fission Neutron Uranium Borehole Logging Technique. GJBX-47(77); SAND 77-0336; 55 pp.(1977)

The prompt fission neutron (PFN) uranium logging technique measures the enhanced epithermal neutron population created by the prompt thermal fission of U 235 to assay uranium mineralization around a borehole. This neutron population exists for several hundred microseconds after a pulsed neutron source produces a burst of high energy (14MeV) neutrons. A feasibility study established the basic relationship between the uranium concentration and the enhanced epithermal neutron count, and defined the major measurement perturbing factors. A laboratory type neutron generator, the Controlatron, was modified for use in the PFN prototype field probe. Comparisons of neutron logs and natural gamma logs taken during a field evaluation clearly define many disequilibrium conditions, thus verifying, by ore grade estimates from core samples, the feasibility of the PFN logging technique to detect uranium in-situ. (Auth)(PAG)

412
Tuovinen, O.H.; Queen Elizabeth College, Microbiology Department, London, England

Microbiological Aspects in the Leaching of Uranium by THIOBACILLUS FERROOXIDANS. Atomic Energy Review 10(1):251-258.(1972)

The chemolithotropic bacteria, THIOBACILLUS FERROOXIDANS, FERROBACILLUS FERROOXIDANS, and FERROBACILLUS SULFOOXIDANS, can be employed to produce and regenerate chemical solutions for dissolving uranium. Such microbiological leaching is regarded as a feasible means for the treatment of low-grade uranium ores that are difficult to exploit by other methods. There are two principal ways in which to exploit low-grade uranium ores via bacterial leaching. The first employs THIOBACILLUS FERROOXIDANS. The oxidation of ferrous iron solutions and the maintenance of a high Fe+3/Fe+2 ratio by these bacteria results in the leaching of uranium by utilizing ferric iron according to the two following reactions: (1) $2FeSO_4 + H_2SO_4 + 1/2O_2 = Fe_2(SO_4)_3 + H_2O$ and (2) $UO_2 + Fe_2(SO_4)_3 = UO_2SO_4 + 2FeSO_4$. The second method of bacterial leaching involves sulfur and iron oxidizing bacteria which assist in the oxidation of the iron sulfides (usually pyrite) which is often associated with uranium ores and uranium-bearing shales. These bacteria make a system more favorable for the leaching of uranium by altering its chemical and physical environment according to the following reactions: (1) $2FeS_2 + 7O_2 + 2H_2O = 2FeSO_4 + 2H_2SO_4$; (2) $FeS_2 + FeS_2(SO_4)_3 = 3FeSO_4 + 2S$; (3) $S + 1\ 1/2\ O_2 + H_2O = H_2SO_4$; (4) $UO_2 + H_2SO_4 + 1/2O_2 = UO_2SO_4 + H_2O$. The redox potential of U+4/U+6 is 410 mV. The maintenance of a high redox potential is a critical factor in the dissolution of U+4 and it is overcome by a high Fe+3/Fe+2 ratio through the

action of THIOBACILLUS FERROOXIDANS. Aeration may have to be provided in IN SITU leach mining in order to maintain a sufficiently high redox potential. Controlling the pH of the waters is also important in IN SITU leach mining. Hydrolysed iron precipitates, such as jarosite and iron phosphates, result in the formation of impermeable iron slimes on mineral grains, thus blocking the contact between the oxidizing agent and the mineral surface. To avoid this, the acidity should be kept below pH 1.8. When pyrite is present in the uranium ore, its oxidation and the oxidation of sulfur by THIOBACILLUS FERROOXIDANS generates sulfuric acid at more or less a constant rate. Under such conditions, the amount of additional sulfuric acid needed to neutralize alkaline material is lessened. Several organic solvents can be used to separate uranium from the acid leaching solutions. These compounds are usually derivates of tertiary amines diluted with kerosene-type solutions. It is desirable to keep the loss of such solvents to a minimum in that they will destroy THIOBACILLUS FERROOXIDANS. Care must also be used when an ion exchange resin is employed to recover the uranium from the leach solution. Resins may absorb the bacteria, and otherwise inhibit their growth or destroy them. Uranium, itself, is toxic to THIOBACILLUS FERROOXIDANS above 0.001 to 0.0005 molar concentrations. Resistance to the uranium develops quickly, however, and some heavy metals and complexing agents can be used to reduce its toxicity. (JMT)

413
Wooten, M.J., C. Hirayama, A.J. Panson, and J.T. Patton; Westinghouse Electric Corporation, Research Laboratories, Pittsburgh, PA

Uranium Recovery from Seawater. PB-253 482; EPRI NP-132; 40 pp.(1976, February)

The experimental study of electrolysis of sea water did not reveal a practical method for recovery of uranium. The electrolysis resulted in deposits of Mg(OH)2 which adsorbed hexavalent uranium from the sea water. Thus, the uranium was not recovered by direct result of electrolysis or valence change, but by an adsorption on Mg(OH)2 which formed on the electrode as a consequence of electrolysis of water and local pH increase at the cathode. The uranium recovery was about 0.1 mg per gram of deposited Mg(OH)2 and thus is to be compared with a recovery of 0.8 mg per gram of adsorber, obtained for direct adsorption experiments in Japan with titanic acid and active charcoal. The electrolytic results obtained thus show no advantage over direct adsorption methods. (MLB)

414
Zefirov, A.

Underground Leaching-A Process for Economical Uranium Extraction from Low-Grade Ores. Russian Report 014; 12 pp.; AEC-tr-6836; 8 pp.(1966)

Underground leaching of uranium deposits permits the enlargement of uranium resources because of the possibilities for exploiting low-grade ores. The process was studied in the types of deposits lying in laminar rocks and in sand-clay strata. The methods of investigation were 1) uranium leaching of large pieces of ore (less than 200 mm), and 2) leaching of strata in their natural stratification. The process of leaching large pieces of ore consists of periodic spraying of the crushed ore. The solutions produced, passing through the entire ore mass, are collected at the bottom. The solutions are directed to a special vessel, and built up at a lower level from where they are transferred to the surface for further treatment. The process of uranium extraction in stratified-type deposits consists of transferring the uranium from minerals to solution by conveying a reagent over the ore stratum through a set of pressure boreholes. The uranium-containing solutions are pumped out from another set of drill holes, arranged at precisely spaced intervals from the pressure drill holes. (PAG)

This paper was translated from Russian by the U.S. Atomic Energy Commission.

RESERVES AND RESOURCES

415
AEC, Grand Junction Office, Resource Division, Grand Junction, CO

Potential Uranium Resources of the Western United States. GJO-104(73); 7 pp.(1973, May)

Reserves and potential resources as of January 1, 1973 were estimated as follows: $8 per pound-273,000 tons U3O8 reserves, 450,000 tons U3O8 potential resources; and at $15 per pound-520,000 tons U3O8 reserves, 1,000,000 tons U3O8 potential resources. Ore reserves (tonnage) are: Colorado Plateau 150,000; Wyoming Basins 97,000; Gulf Coastal Plains 16,000, and others 10,000. Potential resources are (in tonnage): Colorado Plateau 250,000; Wyoming Basins 90,000; Gulf Coastal Plains 50,000; and others 60,000. Total ore reserves as of January 1, 1973 are estimated at 723,000 tons U3O8 (based on $8 per pound cutoff cost). (PAG)

416
Metal Mining Agency of Japan, Tokyo, Japan

Studies on Extraction System of Uranium from Sea Water in Japan. (1977, October)

Japan depends on foreign countries for most of her energy resources, and as a result, it was deemed necessary to begin a period of research and development for the extraction of uranium from sea water. Research began in 1975 and is scheduled to end in the 1983 fiscal year. During this period of time a test plant is to be built, and data for a practical plant are to be accumulated by experimental operation. (JMT)

417
Anderson, J.J., R.M. Feldmann, and D.F. Palmer; American Petroleum Institute, Office of the General Counsel, Kent, OH

A Summary of Reserve and Resource Data on Coal, Uranium, and Oil Shale in the States of Michigan, Ohio, Kentucky, Tennessee, West Virginia, North Dakota, South Dakota, Montana, Wyoming, Colorado, and Utah. TID-27001; 61 pp.(1975, May 12)

Michigan, Ohio, Kentucky, Tennessee, West Virginia, North Dakota, South Dakota, Montana, Wyoming, Colorado, and Utah contain the major portion of the Nation's resources. Michigan contains as much as 705 million tons of coal resources; possible coal reserves of 220 million tons; and 7 occurrences of uranium. Ohio contains as much as 43,358 million tons of coal resources and 21,077 million tons of coal reserves. Oil shale deposits underlie much of E Ohio but they have not been evaluated in a systematic manner. Kentucky coal resources may total 116,842 million tons and coal reserves are estimated at 42,159 million tons. Uranium and oil shale occur largely in the Chattanooga Shale and other black shales which underlie much of the state. Values of these resources are unknown. Coal resources of Tennessee are estimated to be 4,572 million tons and coal reserves are estimated to be 1,000 million tons. Uranium and oil shale resources of Tennessee are found in an estimated 85 billion tons of the Chattanooga Shale. Uranium contents in the Gassaway Member average 0.007 percent. West Virginia coal resources are estimated at 100,628 million tons and coal reserves are estimated at 116,618.5 million tons. Oil shale underlies parts of the state, but is not well evaluated. North Dakota coal resources may total as much as 530,630 million tons and reserves of coal may total 16,003 million tons. Uranium occurs with lignite in some areas near the Montana and South Dakota borders. Total reserves are estimated to be about 1,400 tons of U3O8 within this three state area. Twenty-two occurrences of uranium are known in North Dakota. Forty uranium occurrences are reported in South Dakota. Coal resources for South Dakota are 3,031 million tons and coal reserves are estimated at 114,639 million tons; and 52 occurrences of uranium are reported. Coal resources in Wyoming are 545,656 million tons and reserves of coal total 123,656 million tons. Uranium reserves in Wyoming are estimated to be a minimum in excess of 6 million tons of ore, with possible resources totalling 2-3 times this amount. Uranium occurrences total 188. Oil shale resources of Wyoming are poorly evaluated, although the Washakie Basin may well contain in excess of 1 billion barrels. Colorado contains 371,659 million tons of coal resources, 81,784 million tons of coal reserves, estimated uranium ore resources in excess of 1 million tons (145 occurrences), and oil shale reserves of 1,300 trillion barrels. Utah coal resources are 99,721 million tons, coal reserves are 4,042 million tons; uranium resources are

estimated at 1 million tons (203 occurrences), and oil shale reserves are estimated to be 910 billion barrels. Assumptions of inhibition of development due to federally protected areas are also presented for each state in this survey. (PAG)

418
Bergendahl, M.H.; USGS, Washington, DC

Stratigraphy of Parts of De Soto and Hardee Counties, Florida. USGS Bulletin 1030-B; 98 pp.(1956)

The late Cenozoic stratigraphy of part of central Florida immediately south of the land-pebble phosphate district was studied in detail to determine the southern limit of the economically important Bone Valley Formation and its relationship with marine rocks of Miocene and Pliocene age in south-central Florida. Field studies and radiometric analyses of samples indicated that the uranium resources of the area covered in this report were unimportant under present economic conditions. A total of 135 unsieved samples were analyzed radiometrically for percent equivalent uranium. The results ranged from less than 0.001 percent to 0.009 percent. The average percent equivalent uranium from each of the stratigraphic unit's samples was as follows: Pleistocene deposits = 0.001 percent; Caloosahatchee Marl = 0.003 percent; Undifferentiated phosphatic sand and clay = 0.003 percent; Upper Miocene deposits = 0.002 percent; Hawthorn Formation = 0.003 percent. (JMT)

419
Borg, I.Y., R. Stone, and K.P. Puchlik; Lawrence Livermore Laboratory, Energy and Resource Planning Group, Livermore, CA

Oil, Gas, Uranium, and Thorium: Supply and Depletion. UCRL-52180; 214 pp.(1976, December 24)

Oil, natural gas, uranium, and thorium supplies and depletion forecasts are presented in the report. Uranium reserve estimates reflect detailed evaluations by ERDA's Grand Junction Office of a massive amount of input data furnished on a confidential basis by companies engaged in production and/or exploration activities. Areas of interest by exploration companies in California are the Lakeview District, Antelope Range-Peterson Mt. District, Hawthorne-Walker District, and the Coso Dome Area. Twelve favorable locations for uranium prospecting are indicated for Alaska. Charts and graphs illustrate the marketing and prices of uranium. (PAG)

Numerous tables and graphs are utilized.

420
Bowie, S.H.U.; Institute of Geological Sciences, London, England

Uranium Distribution and Availability. Geology, Mining and Extractive Processing of Uranium, Jones, M.J. (Ed.), Proceedings of a Symposium, London, January 17-19, 1977. Institute of Mining and Metallurgy, London, (pp. 76-82), 171 pp.(1976)

Uranium deposits are not uniformly distributed in the earth's crust but occur in well-defined provinces, mainly in Precambrian terrain and in association with acid igneous rocks. Deposits can conveniently be classified into four main groups: uranium in sandstones; uranium in conglomerates; vein-and similar-type deposits; and other uranium deposits. Most of the presently known reserves occur in sandstones; vein-type deposits are now second in importance, conglomerates are third and other deposits, excluding shales, fourth. The shales of southern Sweden constitute a special case: although recoverable reserves are large (300,000 tons of uranium), annual production from them is not likely to exceed 1000-2000 tons of uranium. The estimation of reserves has been complicated by rapid price rises since 1973 and by uncertainty as to what cost or price levels should be adopted in distinguishing between reserves and resources. Also there has been a tendency for requirements to be revised downwards, and this, together with the apparent acceptance of cost levels of around $30/lb ($66/kg) U3O8, has relieved the medium-term prospects so far as supply is concerned. In the longer term, however, there is clearly a need for increased prospecting effort on a world scale and for the introduction of new search methods, particularly those aimed at the detection of hidden orebodies. (Auth)(PAG)

421
Burnham, J.B., R.E. Brown, P.L. Hendrickson, W.I. Enderlin, R.K. Paasch, M.S. Hanson, W.H. Rickard, J.N. Hartley, R.G. Schreckhise, R.L. Watts, B.W. Gonser, T.W. Zegers, A.R. Matheson, L.M. Foley, J.L. Harris, and D.C. Pittman; Battelle Pacific Northwest Laboratories, Richland, WA

Assessment of Uranium and Thorium Resources in the United States and the Effect of Policy Alternatives. Battelle Report; 211 pp.(1974. December)

Uranium and thorium resources in the US are extensive but new or improved technology and higher prices are required before they will become economically viable. Reasonably assured uranium reserves recoverable at a 1974 forward cost of $15/lb U3O8 should be adequate at least through 1985. Uranium resources in conventional sandstone deposits as estimated by the AEC amount to approximately 2.4 million tons of U3O8 recoverable at forward costs of $30/lb U3O8. This amount should be adequate to the year 2000. This 2.4 million tons excludes unconventional uranium deposits such as marine black shales, marine phosphorites, granites, seawater, Tertiary lake bed deposits, etc. Thorium resources should be adequate to supply all conceivable needs through the year 2000. Capital and manpower resources may be inadequate in the near future. Production capacity may be inadequate in the short term. Cumulative uranium demand through the year 2000 is approximately 2.1 million tons of U3O8. The uranium industry will need an annual growth rate of approximately 8.6 percent between the years 1975 and 2000 if the projected levels of production are reached. Uranium resources recoverable from seawater are of the order of 4 billion tons of U3O8. The estimated cost of production ranges from $30 to $1000/lb U3O8. Alternative policy options available are: Retention, or immediate elimination, of the policy excluding enrichment of foreign uranium for domestic use; Curtailment of uranium export; government purchase and stockpile of foreign uranium; Changes in the availability of public lands for uranium exploration and production; and Changes in the U235 content plant tails. (PAG)

422
Davis, M.; Commission of the European Communities, Nuclear Energy, Electricity and New Energy Sources, Brussels, Belgium

European Needs for Uranium in Relation to World Supply and Demand. Geology, Mining and Extractive Processing of Uranium, Jones, M.J. (Ed.), Proceedings of a Symposium, London, January 17-19, 1977. Institute of Mining and Metallurgy, London, (pp. 1-7), 171 pp.(1977)

Western European demand for uranium (most of which will have to be imported) is quantified and discussed in relation to the needs of North America and Japan and the latest estimates of world uranium resources and production capabilities. The European Community will be the largest purchaser of uranium from a variety of sources on the world market. It is shown that the lower limits of past estimates for uranium demand appear to be the most reliable so far; the causes and effects of uncertainty for the future are outlined, and the need for exploration is emphasized. (Auth)(PAG)

423
Emerson, J.F.; Union Mines Development Corporation, Grand Junction Field Office, Grand Junction, CO

Report on the Bull Canyon District, Delores Plateau Area, Colorado. RMO-455; 29 pp.(1945, November)

A total of 200,000 tons of positive, indicated, and inferred reserves has been calculated for the Bull Canyon District. Some 84 percent of this tonnage is in the inferred category only. Average grades of the reserves are 0.25 percent U3O8 and 2.31 percent V2O5, although grades of the individual ore blocks differ. (Tonnage does not include reserves of the Wild Steer Mine.) Many of the inferred ore areas have a deep rock cover overlying the ore-bearing horizons, thus making exploration by drilling extremely expensive. The greater part of all mineralized occurrences are located in the southern end of the district. Mineralization occurs in the Salt Wash member of the Morrison formation, except for three minor occurrences in the Brushy Basin member of the Morrison. Mineralization is of the roscoelite-vanoxite type with minor amounts of carnotite nearly always found in every occurrence. The amount of carnotite is dependent upon the amount of carbonaceous materials present. (PAG)

424
Fulton, L.J.P.; University of Cincinnati, Cincinnati, OH

Stratigraphy and Sedimentology of Radioactive Devonian-Mississippian Shales of the Central Appalachian Basin. Ph.D. Thesis; 177 pp.(1977)

In the eastern Kentucky area, the Ohio Shale, a black, organic rich, radioactive shale of Late Devonian age, consists of two dominant lithologic types occurring in a distinctive sequence. The two lithologies are brownish-black, organic-rich shale and greenish-gray, organic-poor shale and mudstone. Five to seven stratigraphic subunits can be recognized easily in both the subsurface and outcrop and are traceable over most of eastern Kentucky and into parts of Ohio, West Virginia, and Tennessee. In descending order, these seven units are: Cleveland Shale; Three Lick Bed; Upper, Middle, and Lower Huron Shales; Olentangy Shale; and Marcellus Shale. The first five of these units can be correlated with members of the Ohio Shale in Ohio and the Chattanooga Shale of Tennessee. Correlations are less clear in West Virginia because facies changes obscure the gamma-ray definition of the stratigraphic subunits. The black shale within the Ohio Shale in Kentucky typically contains 30 ppm uranium, while lighter-colored, organic-poor shale contains only 15 ppm. Uranium contents of samples from five stratigraphic subunits in Kentucky ranges from 6 to 74 ppm; with an average of 27.7 plus or minus 3.2 ppm at 90 percent confidence limits. The amount of uranium varies with lithology and geography. The Tennessee and Alabama black shales are the richest in uranium. In Kentucky, the Ohio Shale is estimated to contain 6.28 X 10(E+12) tons of uranium. In the central Appalachian Basin, deposition of black shale as distal facies of turbidites and as shallow, cratonic deposits occurred in response to episodes of deltaic progradation and marine transgression associated with development of the Catskill delta. Transgressive and regressive pulses were controlled by tectonism marginal to the North American craton and related to movement of continental plates. (JMT)

425

Harris, D.P.; University of Arizona, Department of Mining and Geological Engineering, Tucson, AZ

Quantitative Methods for the Appraisal of Mineral Resources. GJO-6344; GJBX-14(77); 836 pp.(1977, January 1)

The report consists of three parts. Part 1 examines the implicit models (Life Cycle and econometric models), and the geostatistical and deterministic classes of explicit models. Part 2 examines the two types of geostatistical models employed to estimate metal endowment or metal resources: deposit models and geochemical models. The "state of the art" of geochemical models of the European School and the resource model of the Program Analysis Unit of Great Britain are described in Part 3. A bivariate model which allows for dependency or independency of deposit tonnage and grades is formulated and a case study on New Mexico uranium deposits is presented. (PAG)

Part 3, Section 3, "A Bivariate Model for Deposit Size and Grade Which Allows for Statistical Dependency and is Not Based upon Crustal Abundance: Theory, Method of Analysis, Demonstration, and a Case Study (New Mexico Uranium)" is abstracted and input separately.

426

Harris, D.P.; University of Arizona, Department of Mining and Geological Engineering, Tucson, AZ

A Bivariate Model for Deposit Size and Grade Which Allows for Statistical Dependency and is No ased Upon Crustal Abundance: Theory, . thod of Analysis, Demonstration, and a Case Study (New Mexico Uranium). GJO-6334; GJBX-14(77); Quantitative Methods for the Appraisal of Mineral Resources, (pp. 3/1-3/110), 836 pp.(1977, January)

A general methodology is described which allows for the removal of the economic effect, the estimation of the dependency relationship, and estimation of the parameters of the grade and tonnage distributions. The methodology is first tested and validated on synthetic data generated from a known model and then, the methodology is applied to the uranium deposits of New Mexico. The case study of New Mexico uranium deposits tests two hypothesis: 1) deposit grade and size (tonnage of ore) are statistically independent, and 2) average grade of the New Mexico population of uranium deposits is crustal abundance. Analysis showed that tonnage and grade of uranium deposits in New Mexico are statistically independent and the average grade of U308 of this population of deposits is far greater than crustal abundance-1800 ppm compared to 2 ppm. This conclusion shows that the resource model of the Program Analysis Unit of Great Britain is not appropriate, but that a bivariate model which allows for dependency or independency of deposit tonnage and grades is required. (PAG)

427

Hogerton, J.F., C.H. Barnes, L. Geller, and D.R. Hill; S.M. Stoller Corporation, New York, NY

Uranium Data. EPRI-EA-400: 113 pp.(1977, June)

The report describes and objectively assesses the available information in the subject areas of reserve estimates, resource estimates, estimates of production capability, and information on marketing. The assessment has been made from the user's standpoint and reflects the contractor's perception of the interests and needs of utilities for information providing insight into uranium supply questions. The most significant finding of this study is the simple lack of availability of data in these major subject areas in sufficient detail to allow the kinds of analyses needed by utilities and others. The report includes a section on possible innovations including: reducing the time lag between discovery and reporting of resource by ERDA, extended codification of ERDA data, reporting statistics on sub-universe basis, and more complete analyses involving cutoff costs. Finally, the report presents specific recommendations for achieving these needed innovations. (PAG)

428
Konstantynowicz, E.

World's Uranium Ores, Resources and Production on the Background of Nuclear Energy Development. Prezeglad Gorniczy 32(5):225-229.(1976, May)

The geochemical environment of uranium is presented. Genetic types of uranium ore deposits are determined and characterized. Attention is drawn to the commercial importance of sedimentary and metamorphic deposits. (MLB)

429
Lieberman, M.A.; University of California, Berkeley, CA

United States Uranium Resources - An Analysis of Historical Data. Science 192(4238):431-436.(1976, April)

ERDA, by its own estimates and projections of growth, has long recognized that a serious shortfall in uranium supply will develop toward the end of the century. In response, evaluation programs assessing potential resources of uranium have been established. Also, embargoes on foreign uranium imports have been lifted and pressure for the liquid metal fast breeder reactor has been applied. Assuming plutonium recycling and an 0.25 percent uranium enrichment tails assay, the year of exhaustion of the U3O8 resource for the various forward cost categories is around 1992. If plutonium is not recycled, then cumulative U3O8 requirements are 25 percent higher, and the year of exhaustion about 1.5 to 2 years earlier. If the estimates are correct, then a severe restriction of U3O8 supply will develop in the late 1980's. To prevent this, one of the following actions should be pursued: (1) Severely limit the growth of nuclear power. (2) Undertake an extensive and successful program of exploration in the intermediate grade range from 500 to 100 ppm of U3O8 by weight. (3) Develop the production of the large western lignite deposits for use in coal-burning and electric power plants, and develop the means for recovery of uranium from the ash (approximately 250 ppm of U3O8). Cost for this U3O8 will be $25 to $45 per pound, and the ash of a 1600-megawatt coal-burning plant will supply the uranium for a 100-megawatt light water reactor. (4) Develop the means to obtain uranium from the Chattanooga shale deposits (cost in the range of $125 to $225 per pound of U3O8). (5) Learn to obtain uranium from seawater. (6) Import the necessary uranium from foreign sources. If any significant growth in US nuclear power is to be sustained over the next few decades, then either a marked increase in the rate of discovery of new, high-grade reserves must occur, contrary to the past trends in exploration statistics, or the development of low-grade ores (lignites, shales, phosphates, or seawater) must be undertaken vigorously. (MLB)

430
Meniove, H.O.; Los Alamos Scientific Laboratory, Los Alamos, NM

NDA Technology for Uranium Resource Evaluation. LA-6709-PR; 9 pp.(1977, February)

The report describes the work performed during the first quarter on the contract for NDA Technology for Uranium Resource Evaluation. The initial phases of the work focused on gamma-ray calculations and computer code modifications in support of borehole logging measurements and surface gamma-ray surveys. The existing gamma-ray transport computer codes at Los Alamos Scientific Laboratory (LASL) are being modified to give the energy group resolution desired for the uranium calculations. Monte Carlo computer calculations have been compared with the discrete ordinates ONETRAN code results for

simple cases to gain confidence in the results. Preliminary calculations have been performed to investigate the applicability of transport and Monte Carlo computer calculations to uranium ore measurements. One of the initial problems is to determine the effect of rock composition, density, moisture content, and borehole diameter on the KUT gamma-ray spectra in the detector. Feasibility studies are in progress to investigate the use of a photoneutron source for direct measurement of the uranium concentration surrounding a borehole. An Sb 124-Be neutron source was used for the initial laboratory test experiments, and a He 4 gas proportional counter was used to count the induced prompt fission neutrons. More efficient fast-neutron detectors are being evaluated and Monte Carlo computer calculations are being used to optimize the source, shield, and detector parameters. A new approach is being investigated for producing photoneutrons by means of converting a beta-decay source to a bremsstrahlung spectrum. The high-energy portion of the spectrum then interacts with a beryllium sleeve to give the photoneutrons. This photoneutron source has the advantage of being a subthreshold neutron source with a convenient half-life. Also, by removing the bremsstrahlung conversion material, such as lead or thorium, the gamma-ray and neutron source can be partially turned off when not in use. Initial measurements have been performed using a Sr 90 beta-decay source combined with lead for the bremsstrahlung conversion. (Auth)

431
Menlove, H.O.; Los Alamos Scientific Laboratory, Los Alamos, NM

NDA Technology for Uranium Resource Evaluation, January 1 - March 31, 1977. LA-6840-PR; 22 pp.(1977, June)

The report describes the work performed during the time period from January 1 - March 31, 1977, on the contract for NDA Technology for Uranium Resource Evaluation in Group Q-1. The work has focused on gamma-ray calculations and computer code modifications in support of borehole logging measurements and surface gamma-ray surveys. The major modifications have been completed on the gamma-ray transport computer codes at the Los Alamos Scientific Laboratory (LASL) to give the fine energy group resolution desired for the uranium calculations. Monte Carlo calculations have been compared with discrete ordinates ONETRAN calculations to gain confidence in the results and to check absolute flux values. The Phase I calculations for uranium, potassium, and thorium gamma-ray spectra have nearly been completed. For the simple Phase I case, the rock was assumed to be an infinite homogeneous medium of sandstone or shale with different porosities and water saturations. To permit the many-group ONETRAN calculations to be performed in a more convenient and efficient manner, the MIXCB code has been developed to give mixed cross-section files corresponding to the various rock compositions, and the ONEPLT code provides the capability of displaying the results in a variety of formats. The Phase II calculations deal primarily with gamma-ray surface and airborne surveys. The initial calculations are to determine the spectra as a function of position above and below a plane interface. Preliminary studies have been performed to determine appropriate values of the ONETRAN parametrs P sub n and S sub n for this configuration. Feasibility studies are continuing to investigate the use of a photoneutron source for direct measurement of the uranium concentration surrounding a borehole. A Sb 124-Be neutron source and a He 4 gas proportional counter for counting the induced prompt fission neutrons were used for the initial laboratory test experiments. A U 235 fission chamber has been used to map the neutron flux from the Sb 124-Be interrogation source in sand, and a small Cf 252 source was used to measure the spatial dependence of the response from the He 4 fast-neutron detector. In addition, a small sample of enriched U 235 has been used to measure the position dependence for the combined Sb 124-Be interrogation and fast fission neutron return to the He 4 detector. More efficient fast-neutron detectors are being evaluated and Monte Carlo computer calculations are being used to optimize the source, shield, and detector parameters. (Auth)

432
Morse, J.G., and M.S. Curtin; Colorado Energy Research Institute, Golden, CO; Colorado School of Mines, Golden, CO

Colorado Energy Resources Handbook Volume 3: Uranium. Colorado School of Mines Handbook; 68 pp.(1977, December)

Colorado's uranium deposits occur in two geologically distinct areas: western Colorado (west of the Continental Divide) and the Front Range (east of the Continental Divide). Western Colorado is the oldest uranium mining area in the United

States. Most deposits occur in sandstone formations, with uraninite, coffinite, and carnotite ores predominating. From 1948 through 1974, western Colorado produced 12 percent of the total United States uranium ore mined. This amounted to 35,556 short tons of U_3O_8 from 15,589,100 tons of ore averaging 0.23 percent U_3O_8. In addition, 175,261 tons of vanadium oxide (V_2O_5) were recovered. In the Front Range, uranium deposits usually occur as veins, with small bodies of pitchblende commonly associated with sulfide minerals. Usually, the uranium minerals constitute only a small fraction of the vein; most veins are chiefly valued for their gold content, and as a result, there has been little activity connected with uranium in the Front Range area. A notable exception to this is the Schwartzwalder Mine, located in Jefferson County. It is the largest uranium mine in Colorado, producing approximately one-sixth of the state's 1976 uranium output. (JMT)

433
Nathan, Y., and Y. Shiloni; Israel Geological Survey, Geochemistry Division, Jerusalem, Israel; Israel Geological Survey, Mineral Resources Division, Jerusalem, Israel

Exploration for Uranium in Phosphorites: A New Study on Uranium in Israel Phosphorites. CONF-760316; IAEA-SM-208/29; Exploration of Uranium Ore Deposits, Proceedings of a Symposium, Vienna, March 29-April 2, 1976. International Atomic Energy Agency, Vienna, (pp. 645-655), 807 pp.(1976)

Two hundred and fifty-four samples from nine phosphate fields and one oil shale deposit overlying phosphorites were examined for P_2O_5 and organic matter. The fields showed significant differences in uranium content; relatively rich fields in uranium, like Zefa had a normalized mean of 5.9 ppm uranium per 1 percent P_2O_5, while others such as Saraf had a mean of 3.5 ppm. The Zefa field had 28 percent P_2O_5 and the Saraf field had 25 percent. The uranium concentration of the seawater (interstitial water) is believed to have been the dominant factor in uranium precipitation and concentration. Accordingly, it should now be possible to choose and reserve the appropriate raw material to obtain the highest yields of phosphoric acid and uranium, and to use other phosphorites less rich in uranium for other purposes. (Auth)(JMT)

434
Shelton, J.W., Z. Al-Shaieb, R.W. Olmsted, R.E. Hanson, R.T. May, and R.T. Owens; Oklahoma State University, Department of Geology, Stillwater, OK

Summary of the Stratigraphy, Sedimentology, and Mineralogy of Pennsylvanian and Permian Rocks of Oklahoma in Relation to Uranium-Resource Potential. GJBX-20(76); 156 pp.(1976, February 27)

Pennsylvanian-Permian strata in Oklahoma were deposited in environments which ranged from deep marine to alluvial fan. The former was most common in the Ouachita geosyncline during Early Pennsylvanian, but parts of the Anadarko basin were also relatively deep water during Middle and Late Pennsylvanian. Alluvial-fan deposits in Oklahoma are related primarily to the Amarillo-Wichita-Criner, Arbuckle, and Ouachita uplifts. As a result of erosion of the Wichita and Arbuckle areas during the Pennsylvanian-Permian, Precambrian and Cambrian felsic igneous rocks were exposed and became sources of significant quantities of feldspar in the sandstones and conglomerates, especially those on the flanks of the uplifts, and possibly sources of significant uranium concentrations in basinal waters. The Ouachita uplift, Sierra Grande-Apishapa uplift to the northwest, and possibly the Appalachian system also furnished feldspar to form the rather common subarkoses in the Upper Pennsylvanian-Permian. Feldspar is an apparent source of uranium which is present in the alluvial-fan deposits associated with the Wichita and Arbuckle uplifts, the Permian sandstones on oil-producing structures in southern Oklahoma, the lenticular sandstones on the Muenster-Waurika arch, and the tidal-flat sandstone-siltstones in western Oklahoma and possibly in north-central Oklahoma. Radioactive anomalies associated with Cherokee sandstones may be related to the Desmoinesian phosphatic shales, local depositional environments of deltaic complexes which influenced diagenetic conditions, and/or the pre-Pennsylvanian unconformity with respect to the radioactive Woodford Shale. (Auth)

435
Silver, J.M., and W.J. Wright; Australian Atomic Energy Commission, Canberra, Australia

Uranium: The World Picture. South Africa Mining and Engineering Journal 88:45-53.(1976, July)

The world resources of uranium and the future demand for uranium are discussed. The amount of uranium available depends on the price which users are prepared to pay for its recovery. As the price is increased, there is an incentive to recover uranium from lower grade or more difficult deposits. In view of this, attention is drawn to the development of the uranium industry in Australia. (MLB)

436
Smith, C.T.; Union Mines Development Corporation, Grand Junction Field Office, Grand Junction, CO

Report on Rifle Mine Locality, Grand Hogback District, White River Uplift Area, Colorado. RMO-442; 108 pp.(1946, April)

The Rifle Mine, Garfield County, Colorado was studied to determine the uranium resources available from the Entrada Formation. The Entrada Formation has a much lower grade of ore than the Morrison Formation, and averages 0.05 percent U308 and 1.45 percent V205 with an average ore grade of 3. Tonnage is calculated at 660,000 and an additional 106,000 tons of tailings. The major portion of the ore of the Rifle Mine lies in an irregular, roughly lenticular, bedded deposit in sandstone. The ore usually has well-defined walls and varies in thickness from less than 1 ft. to about 30 ft. Fault zones cut the ore bodies at angles of about 60 to 70 degrees to the strike of the ore lenses and dip from 60 degrees to vertical. The displacement on individual faults is seldom more than 6 to 10 ft. (PAG)

437
Zitting, R.T.; Kerr-McGee Nuclear Corporation, Oklahoma City, OK

Estimation of Potential Uranium Resources. Mineral Resources and the Environment, National Academy of Sciences, Washington, DC. (pp. 142-154), 236 pp.(1975)

The availability of uranium in this country will not be limited by nature. The problem of adequate supply becomes one of our industry's ability to meet legitimate requirements as the use of nuclear power expands. Much of the concern in the utility industry regarding the long term uranium supply situation results from the recent switch in the purchasing patterns of the utility industry from principally short term contracting to interest in purchasing uranium for delivery under very long term contracts (as much as 20 years in the future). Thus, the buyers of uranium have switched from a pattern of uranium buying close to that of fuel oil contracts (two to three years of forward requirements) to a pattern more closely paralleling coal purchase contracts which approach fuel supply commitments for life of the plant. To a large extent, it is this switch in purchasing objectives rather than actual supply conditions that has focused attention on the availability of uranium during the 1980's. However, the domestic uranium supply picture has improved substantially in contrast to the deteriorating situation for the domestic oil and gas industries. The current reserve to production ratio for uranium is approximately 20 based on the AEC's estimate of reserves recoverable at costs up to $8 per pound of U3O8, and between 30 and 35 based on reserves recoverable at costs up to $15 per pound of U3O8, whereas, the ratio for oil and gas has declined to about 11. Considering that new uranium mines have an average life on the order of ten years, it would seem that on the surface this is a satisfactory reserve position for uranium. However, based on the expected production capability of reserves in these categories, it is estimated that the demand will outstrip potential production capacity by 1980. Therefore, if one judges the sufficiency of reserves in terms of the industry's ability to contract long term (i.e., into the 1990's) the present discovered reserves are clearly insufficient in terms of that criterion. (MLB)

GEOLOGY OF POTENTIAL URANIUM-BEARING AREAS

438
Al-Shaieb, Z., R.W. Olmsted, J.W. Shelton, R.T. May, R.T. Owens, and R.E. Hanson; Oklahoma State University, Geology Department, Stillwater, OK; ARCO, Denver, CO

Uranium Potential of Permian and Pennsylvanian Sandstones in Oklahoma. American Association of Petroleum Geologists 61(3):360-375.(1977, March)

Uranium and radioactive anomalies in Pennsylvanian and Permian sandstones in Oklahoma are related to one or several of the following factors: (1) relatively high feldspar content, (2) hydrocarbon seepage or production, (3) relatively common organic matter, (4) evaporitic depositional conditions. Several combinations of these factors are expressed in the geologic frameworks in which anomalies are present: (1) feldspathic Permian sandstones in oil-producing structures, (2) alluvial-fan deposits associated with the Wichita and Arbuckle uplift, (3) lenticular sandstones on major structural elements in southern Oklahoma, (4) tidal-flat (possible sabkha) sandstones-siltstones in western Oklahoma, and (5) deltaic-alluvial Cherokee sandstones (or oil/or brine produced from them). (MLB)

439
Brown, T.E.; University of Texas, Bureau of Economic Geology, Austin, TX

Index to Areal Geologic Maps in Texas, 1891-1961. University of Texas Map Index; 20 pp.(1963)

The index brings up to date the "Geologic Map Index of Texas" compiled by Leona Boardmam for the United States Geologic Survey for the period up to 1951 and also incorporates unpublished geologic maps in theses and dissertations. Maps are grouped by date of publication. The oldest group, comprising 93 items was published from 1891-1936; the second group of 92 items was published from 1937-1950; the youngest group, containing 81 items, was published from 1951-1961. For central Texas where map density is high, two enlarged insets are included. The index includes published and unpublished maps at a scale of 1:250,000 or larger, and also maps smaller than 1:250,000. The 93 smaller-scale maps are also listed. (JMT)

Cited as a reference in NURE Contractor Reports.

440
Byerly, P.E., and H.R. Joesting; USGS, Denver, CO

Regional Geophysical Investigations of the Lisbon Valley Area, Utah and Colorado. USGS Professional Paper 316-C; 11 pp.(1959)

Aeromagnetic and gravity surveys were conducted in the Lisbon Valley area as part of a study of the regional geology of the Colorado Plateau. Exposed rocks range in age from Pennsylvanian to Quaternary, and include, in the northern part of the area, the intrusive rocks of the La Sal Mountains of probable Tertiary age. The major structure in the area is the Lisbon Valley faulted salt anticline, with its accompanying negative gravity anomaly of about 15 milligals. The magnetic anomalies and trends in the Lisbon Valley area are apparently caused predominantly by small to moderate variations of the magnetization of the basement rocks and to regional structural trends in the basement. The gravity anomalies are due both to changes in the thickness of the evaporites in the Paradox member of the Hermosa Formation and to intrabasement density contrasts. The gravity anomalies complement the magnetic anomalies in the southwestern part of the area, indicating local east-west compositional trends within the basement rocks. The alinement of the South Mountain group of igneous intrusions in the La Sal Mountains, the salt plug north of Pine Ridge, and the Gypsum Valley piercement structure, suggest that the South Mountain group of intrusions was injected along a zone of intrabasement structure, probably a fault zone, which originated before or during late Paleozoic time. (JMT)

441
Dickson, R.E., D.P. Drake, and T.J. Reese; Bendix Field Engineering Corporation, Grand Junction Operations, Grand Junction, CO

Measured Sections and Analyses of Uranium Host Rocks of the Dockum Group, New Mexico and Texas. GJBX-9(77); 68 pp.(1977, February)

Twenty-seven stratigraphic sections from the Dockum Group of Late Triassic age, in the southern High Plains of eastern New Mexico and northwestern Texas were measured and sampled--most of these are partial sections. A total of 334 rock samples were collected during the section measuring. The Dockum Group consists of fluvial, lacustrine, and paludal deposits. It is composed predominantly of sandstones, mudstones, and conglomerates. Thin limestone beds occur locally. The Dockum ranges from a feather-edge to more than 2,000 ft thick. Exposed Dockum sandstones are light- to medium-gray, white, yellow, brown, red; predominantly very fine- to medium-grained, poorly to moderately sorted, subangular to subrounded, calcareous quartz sandstones. They consist of as much as 96 percent quartz grains. Chert, clay, feldspar, mica, heavy minerals, and sedimentary rock fragments are present. There is abundant clay content and, locally, granules and pebbles are common. Calcareous cement constitutes small proportions of some rocks and substantial proportions of others. Clays also cement some sandstones and conglomerates. Infrequently, hematite and limonite may serve as cement. There are substantial amounts of opaline silica cement in some sandstones, and dolomite cement is also present. Dockum Group conglomerates are of two main types: (1) siliceous-pebble conglomerates, which are widespread in the southern High Plains and (2) limestone-pebble conglomerates, which are present in the southeastern area but are less important toward the north, in the Texas Panhandle. Feldspar content of the sandstones and conglomerates ranges from traces up to about 20 percent. Many samples have less than 5 percent feldspar. The shale and claystone of the Dockum are predominantly red; but they are also medium and dark gray, green, purple, and saffron yellow. The coloration is uniform to banded, streaked, speckled, and mottled. The contrast between the darker brownish-red, purple, and saffron yellow shale, claystone, and siltstone beds of the Dockum and the underlying, more uniformly brick-red Permian rocks is striking in the northeastern escarpment in the Texas Panhandle. (PAG)

Locations of the sections and descriptions of the thickness of sample intervals are presented in Appendix A. Modal analyses (by thin-section examination) of sandstone and conglomerate samples are presented in Appendix B. Gamma-ray spectrometric analyses of the samples are presented in Appendix C.

442
Eakins, G.R.; Alaska Department of Natural Resources, Division of Geological and Geophysical Surveys, College, AK

Uranium Investigations in Southeastern Alaska. Geologic Report 44; 62 pp.(1975)

Radioactive mineral deposits at 14 localities in Southeastern Alaska are discussed to assist in the exploration for uranium. These areas were selected because of known or reported radioactivity and (or) favorable geology. Vein deposits and nonmarine Tertiary sandstones were examined. Radiometric surveys were made on foot, and small areas were mapped to show the spatial relationship between radioactivity and certain ore deposits. Previously unreported low radioactive anomalies were found at several localities, but none of the deposits was indicated to be of commercial grade. Slightly radioactive sandstones were found at Port Camden and on the west side of Zarembo Island. Radioactive pegmatites at Endicott Arm and elsewhere in Southeastern Alaska do not appear to have commercial possibilities, but may serve as guides to mineralization. Geochemical stream-sediment samples were collected at most of the localities examined. A total of 205 samples were taken. Results of atomic absorption analyses are given for copper, lead and zinc. Strong geochemical anomalies were found at William Henry Bay and Kook Lake. The best guides for uranium exploration in Southeastern Alaska are soda-rich granite and the ores and gangue minerals frequently associated with uranium. These include minerals containing copper, silver, cobalt and molybdenum, and hematite and fluorite. There is some indication that unusual amounts of uranium minerals are present in zones peripheral to major copper districts. (Auth)

443
Galloway, W.E., T.D. Murphy, R.C. Belcher, B.D. Johnson, and S. Sutton; Texas Bureau of Economic Geology, University of Texas, Austin, TX

Catahoula Formation of the Texas Coastal Plain: Depositional Systems, Composition, Structural Development, Ground-Water Flow History, and Uranium Distribution. GJBX-41(77); Report of Investigations No. 87; 59 pp.(1977)

The Catahoula Formation of the Texas Gulf Coastal Plain consists of two depositional systems-the Gueydan bedload fluvial system of the Rio Grande embayment and the Chita-Corrigan mixed load fluvial system of the Houston embayment. Both systems contain distinctive fluvial channel-fill, crevasse splay, floodplain, and lacustrine facies, which tend to persist vertically through the section. The paleoclimate varied from subarid in the Gueydan system to humid in northeastern parts of the Chita-Corrigan system. Gueydan sands are dominated by plagioclase feldspar and volcanic rock fragments reflecting a western source; in contrast, Chita-Corrigan sands are quartzose and were primarily reworked from mixed sedimentary terranes. Clay composition reflects alteration to montmorillonite and kaolinite of large volumes of volcanic ash deposited in both systems in response to pedogenesis and shallow burial diagenesis. Growth faults initiated by early Tertiary deltaic progradation extend up into the Catahoula and profoundly influence trends of fluvial sand units and post-depositional ground-water flow. Consequently, fault zones may localize uranium mineralization, but faulting is not necessary for development of commercial deposits. Diagenetic features, distribution of trace uranium in fine-grained tuffaceous facies, and reconstructed groundwater flow history in the Catahoula provide the basis for interpretation of a terrigenous coastal plain uranium cycle. The inferred uranium cycle provides criteria that can be used to compare the uranium potential of the Gueydan and Chita-Corrigan fluvial systems and to determine the possible distribution and nature of mineralization within each depositional system. These criteria apply similarly to other potential coastal plain uranium host systems. (Auth)

444

Geology Division Staff; Bendix Field Engineering Corporation, Grand Junction, CO

Uranium Favorability of the Fort Union and Wasatch Formations in the Northern Powder River Basin, Wyoming and Montana. GJBX-58(76); 29 pp.(1976, October)

The investigation was conducted to assess the favorability for uranium resources in the northern Powder River Basin. Emphasis of the study was on mapping subsurface lithofacies in order to identify favorable host-rock trends in early Tertiary fluvial strata. Interpretation of results from the subsurface study, as well as results from examination of outcrops, petrographic and chemical analysis of outcrop samples, and literature research, provided the basis for favorability assessment. The study was limited to the Paleocene Fort Union formation and Eocene Wasatch formation, both of which are host to significant uranium deposits in the southern part of the basin. These formations consist of deposits of flood-plain, paludal, and lacustrine environments. The structural configuration of the basin partly controlled deposition of Fort Union and Wasatch fluvial sediments. Persistence of the same depositional patterns throughout the two formations indicates that structural controls of drainage were constant. Favorable host rocks, in the form of channel sandstones with carbonaceous detritus, are present in both the northern and southern parts of the basin and are part of the early Tertiary drainage system in the Powder River Basin. Comparison between the parts of the basin shows that the Fort Union and Wasatch are lithologically similar. Although favorable host rocks are present in the project area, additional favorable criteria for uranium resources in the northern Powder River Basin are either difficult to demonstrate or absent. The favorability assessment rating for most of the project area is poor. (MLB)

445

Jordan, R.R.; Delaware Geological Survey, Newark, DE

Survey of Nonmarine Cretaceous Sediments of New Jersey, Delaware, and Maryland and Their Uranium-Bearing Potentials. GJO-7403; 65 pp.(1970, June)

The report deals with the nonmarine Cretaceous units of the Atlantic Coastal Plain in Maryland, Delaware, and New Jersey. These deposits are stratigraphically divisible into the Potomac Group, including the Patuxent, Arundel, and Patapsco formations, in part of Maryland, the Raritan Formation of northern New Jersey, and the Magothy Formation. These form a thick complex of continental clay and sand spread eastward from sources in the Appalachian Mountain System. The sediments dip in general toward the Atlantic Ocean, but there are subtle structural variations on this trend. The rocks are considered in detail only to a depth of 1000 feet. The Potomac and Raritan sediments represent a fluvial-deltaic complex in which large fans fed into low-gradient deltas that shifted laterally along the coast. The Magothy represents a

transition to marine conditions through coastal marshes. The large quantities of fluvial sandstone, the age of the deposits, and the presence of considerable organic debris, especially in the Arundel, Raritan, and Magothy are similarities to the uranium-producing sandstones of the Colorado Plateau that suggest that the Coastal Plain deposits may be worthy of further investigation for uranium. Negative factors are the seeming lack of source rocks and the combination of tectonics and hydrology that were so effective in the Plateau. The analogy, nonetheless, appears sufficiently strong to warrant further investigation, at least through a detailed investigation of an organic-rich horizon. (Auth)

446
Ketner, K.G., and L.J. McGreevy; USGS, Washington, DC

Stratigraphy of the Area Between Hernando and Hardee Counties, Florida. USGS Bulletin 1074-C; 124 pp.(1959)

Eocene, Oligocene, Miocene, and Recent rocks are exposed between Hernando and Hardee Counties. Eocene and Oligocene formations are fossiliferous limestones, but Miocene rocks are largely unconsolidated sands and clays in which fossils are scarce. Hard rock phosphate deposits in the area are in beds of early Miocene age, which are assigned to the Tampa limestone. Uranium is concentrated in the lower part of the sand unit and the upper part of the phosphorite unit of the Hawthorn Formation where, according to current interpretation, it is precipitated from solutions carrying it downward from the upper part of the formation. (JMT)

447
Lajoie, K.R.; University of California, Geology Department, Berkeley, CA

Late Quaternary Stratigraphy and Geologic History of Mono Basin, Eastern California. Ph.D. Thesis; 271 pp.(1968)

Mono Basin, a closed tectonic depression at the base of the steep Sierran escarpment east of Yosemite National Park, held a succession of deep lakes, collectively referred to as Lake Russell, during late Pleistocene time. Mono Lake presently occupies the floor of the basin below 6,400 feet. Near-shore sand and gravel deposits form two prominent depositional terraces at about 6,740 and 6,640 feet and interfinger with a 20-50 foot bed of light gray, finely laminated, ostracod-bearing, clayey silt, here named the Wilson Creek formation. Eighteen rhyolitic ash layers derived from the Mono Craters and two basaltic ash layers derived from Black Point occur in this formation in five distinctive marker sequences and provide a means of detailed stratigraphic correlation throughout Mono Basin. Three hundred feet of discontinuously exposed lacustrine silt and diatomite are exposed beneath the Wilson Creek formation on Paoha Island. Rare authigenic struvite crystals occur in the lower part of the Paoha Island sequence and are altering to newberyite and other unknown phosphates. Rhyolitic ash from lacustrine silts is correlated with the Mono Craters by means of trace-element ratios determined by rapid-scan x-ray fluorescence techniques. The chemically homogenous Mono Craters (75-76 percent SiO_2) and their southern extension, the chemically heterogenous Inyo Craters (70-76 percent SiO_2), consist of plugs, domes, coulees, and lapilli craters. Rhyolitic and rhyodacitic plugs and spines (67-70 percent SiO_2) in the center of Mono Lake uplifted late Pleistocene lacustrine sediments to form Paoha Island. Hot spring activity on the island and near Black Point indicates that volcanic activity has not died out in the area. Structural down-warping which formed the basin is still in progress. (Auth)(MLB)

Numerous figures and photographs are included in this report.

448
Mace, E.V.; AEC, Grand Junction Office, Geologic Branch, Grand Junction, CO

Reconnaissance of the Red Canyon Area, San Juan County, Utah. TM-100; 8 pp.(1957)

The principal objectives of the reconnaissance were to locate areas favorable to the occurrence of uranium ore, to study the geologic environment of the ore deposits, and to collect data for regional geologic studies of the Shinarump member of the Triassic Chinle Formation. The studies revealed no new criteria for discovery of uranium deposits but a greater knowledge was gained of the regional distribution, lithology, and sedimentary trends of Shinarump strata and a study was begun of the regional paleostream drainage pattern in the Red Canyon area. As a result of the reconnaissance of the Red Canyon area, the

Posey, Blue Lizard, and Markey localities were recommended for physical exploration by diamond drilling. (Auth^MLB)

Maps and tables are included in this report.

449
Marjaniemi, D.K., W.E. Curry, and J.W. Robins; Bendix Field Engineering Operation, Grand Junction Operations, Grand Junction, CO

Uranium Favorability of Cenozoic Sedimentary Rocks of the Western Snake River Basin, Idaho. GJBX-57(76); 65 pp.(1976, October)

Cenozoic sedimentary rocks in the western Snake River basin of Idaho were studied to determine their favorability for uranium resources. Effort was concentrated on formations that are widely exposed in the area and that contain thick sequences of consolidated or partially consolidated sedimentary rocks. The western Snake River basin of Idaho is a large basin containing a thick sequence of Tertiary sedimentary rocks, and is adjacent to the Idaho batholith that contains possible uranium source rocks. The dips of the sedimentary beds are gentle; there are no unconformities in the sedimentary sequence; there is much faulting of the sedimentary beds; and the Tertiary sequence contains thick tuffaceous beds. The formations evaluated and their uranium potentials are: Sucker Creek Formation, greatest favorability; Poison Creek Formation, moderately favorable; Payette Formation, least favorable, and the Idaho group, least to greatest favorability depending upon depth interval and location in the basin. (Auth)(PAG)

Data for this report are contained in GJBX-57(76)a, "Addendum to Uranium Favorability of Cenozoic Sedimentary Rocks of the Western Snake River Basin, Idaho."

450
Marjaniemi, D.K., W.E. Curry, and J.W. Robins; Bendix Field Engineering Corporation, Grand Junction, CO

Addendum to Uranium Favorability of Cenozoic Sedimentary Rocks of the Western Snake River Basin, Idaho. GJBX-57(76)a; 64 pp.(1976, October)

The Sucker Creek Formation, Poison Creek Formation, Payette Formation, and the Idaho Group in the western Snake River basin of Idaho were evaluated as to their uranium resource potential. Stratigraphic and lithologic data for sample locations; gamma ray spectrometric analyses of rock samples; semiquantitative emission spectroscopic analyses of selected rock samples; average concentrations of trace elements in samples analyzed by emission spectroscopy; petrographic analyses of selected samples; uranium analyses of water samples, a list of water wells; and a list of petroleum test wells comprise the data contained in the appendices. (PAG)

This report is the appendices to GJBX-57(76).

451
Marjaniemi, D.K., and J.W. Robins; Lucius Pitkin, Incorporated, Grand Junction, CO

Uranium Favorability of Tertiary Sedimentary Rocks of the Western Okanogan Highlands and of the Upper Columbia River Valley, Washington. GJBX-2(76); 64 pp.(1975, August)

Tertiary sedimentary rocks in the northern portions of the western Okanogan highlands and in the upper Columbia River valley of northeastern Washington were investigated to determine the favorability for uranium deposits. The project involved measurement and sampling of surface sections, collection of samples from isolated outcrops, and chemical and mineralogical analyses of samples. No portion of the project area of this report was rated of high or of medium favorability for potential uranium resources. Low favorability ratings are given to Oroville, Tonnasket, and Pine Creek areas of the Okanogan River valley; to the Republic graben; and to the William Lakes, Colville, and Sheep Creek areas of the upper Columbia River valley. All these areas contain some fluvial, poorly sorted feldspathic or arkosic sandstones and conglomerates. These rocks are characterized by very low permeability and a consistently high siliceous matrix suggesting very low initial permeability. There are no known uranium deposits in any of these areas, and low level uranium anomalies are rare. (JMT)

452
Noel, J.A.; Indiana University, Geology Department, Bloomington, IN

The Geology of the East End of the Anaconda Range and Adjacent Areas, Montana. Ph.D. Thesis; 74 pp.(1956)

The study of the Anaconda area extended and enlarged the geologic mapping of southwestern Montana. It showed that rocks ranging in age from Algonkian to Recent except for Ordovician and Silurian are present within the area. The presence of the Dinwoody formation in the southeast and possibly the Ellis formation in the northwest indicates that the area may be a transitional point north and west from which all the Triassic rocks, if deposited, have been eroded away and south and east from which all Ellis rocks, if deposited, have been removed. The youngest rocks involved in the Laramide folding, thrusting, and intrusion are those of Upper Cretaceous age. Post-crystallization movement of the batholith is indicated by the foliation resulting from flaser structure. No evidence was found of pre-intrusion volcanism. The flows represent two separate stages separated by a unit of tuff. The Anaconda Range has undergone considerable glaciation. Placer gold has been the most productive of the mineral deposits. (MLB)

453
Pierce, H.W., N. Jones, and R. Rogers; Arizona Bureau of Geology and Mineral Technology, Geological Survey Branch, Tucson, AZ

A Survey of Uranium Favorability of Paleozoic Rocks in the Mogollon Rim and Slope Region-East Central Arizona. Arizona Bureau of Geology and Mineral Technology Circular 19; 71 pp.(1977)

Paleozoic strata of Pennsylvanian and/or Permian age contain laterally persistent zones that are favorable hosts for the occurrence of uranium, both in outcrops and in the subsurface. Outcrop study indicates that portions of certain stratigraphic units were fluvially deposited and contain channel-fill conglomerates and associated sandstones, siltstones, and mudstones. Fossil vegetable matter, in the form of either imprints, carbonaceous films or coalified material, though in variable amounts, also is widespread. The largest prospect is beneath Promontory Butte near Christopher Creek in Gila County. This occurrence is of the peneconcordant tabular variety with a reduced zone mineralogy developed in various lithologies associated with what is believed to have been a point-bar fluvial depositional environment. Limestone pebble conglomerate and associated finer-grained clastics contain coalified plant debris. The uranium is believed to be present in coalified material as uraninite. Associated sulfides in small entities include chalcopyrite, bornite, chalcocite, covellite, galena, sphalerite, pyrite, and marcasite. Mineralization is believed to be related to diagenetic processes and associated ground waters, and to be Paleozoic in age. Lithification, combined with lack of severe post-mineral fracturing, has served to protect the occurrence from subsequent destruction by near-surface oxidizing environments. Associated flora and fauna are fresh water forms that are either latest Pennsylvanian or earliest Permian in age. Regionally, anomalous uranium and anomalous radioactivity (subsurface) is within strata assigned to either the Naco Formation or the base of the Supai Formation. To the east, conglomerates are within a sequence that contains thin marine units while to the west the conglomerates are associated with rocks having an increasingly less obvious marine aspect. The conglomerates are thought to be laterally related and of significance in regional correlations. (PAG)

454
Swanson, R.W.; USGS, Washington, DC

Geology and Phosphate Deposits of the Permian Rocks in Central Western Montana. USGS Professional Paper 313-F; 54 pp.(1973)

The geology of the Permian phosphate deposits in central western Montana is discussed. None of the samples analyzed contained as much as 0.020 percent equivalent uranium, but approximately 30 percent of the samples did contain at least 0.010 percent. In general, the uranium content of the Phosphoria strata is roughly proportional to the P_2O_5 content. In phosphate zones of minable thickness and grade, the eU content ranged from 0.004 to 0.15 percent with an average of about 0.009 percent. (JMT)

MINERALOGY

455
Arribas, A.; Junta de Energia Nuclear, Madrid, Spain

Mineralogia de los Yacimientos Espanoles de Uranio. International Geological Congress, Proceedings of a Conference, Copenhagen, Denmark, 1960. Part 15, Genetic Problems of Uranium and Thorium Deposits, (pp. 99-108), 164 pp.(1960)

The mineralogical characteristics of Spanish uranium deposits and mineral species found to date are summarized. In this review of mineralogical associations and metallogenic features of the main deposits of Spain, deposits are grouped according to their origin so analogies with other deposits can be established. Thorium deposits are not included in this work, except where thorium and uranium appear together, and the relative proportion of both elements is pointed out. (PAG)

456
Atia, A.; Columbia University, Geology Department, New York, NY

Differential Thermal Analyses and High Temperature X-Ray Study of Uraninite. Ph.D. Thesis; 97 pp.(1964)

Phase transformations in UO2 up to 1000 degrees C have been studied by differential thermal analysis and by high temperature x-ray diffraction. In the absence of thorium and rare earths, uraninite is characterized by an exothermic reaction when heated in air to 685 degrees to 710 degrees C. This reaction involves the transformation of UO2 into U3O8. The change may be detected with the high temperature x-ray camera, where diffractometer lines indicate that U3O8 starts to form at 500 degrees to 600 degrees C and exists together with UO2 up to 700 degrees C when UO2 transforms completely into U3O8. In the presence of thorium the UO2-U3O8 reaction is suppressed because of the substitution of U+(4) by Th+(4) which tends to stabilize the UO2 structure. X-ray data show that a large content of rare earth elements breaks down the UO2 structure abruptly at 610 degrees C. Samples high in these elements give more or less differential thermal analysis curves without exothermic or endothermic reactions when heated in air. Artificial UO2 is characterized by an endothermic reaction at 340 degrees C. This is followed by an exothermic reaction at 385 degrees C indicating the transition to U3O8 which is stable up to 1000 degrees C. Artificial UO3 is characterized by an exothermic reaction at 690 degrees C where it becomes U3O8 and is stable up to 1000 degrees C. Artificial U3O8 yields a broad exothermic peak throughout the entire heating range indicating gradual transformations. (Auth)(MLB)

457
Austin, S.R.; AEC, Grand Junction Office, Production Evaluation Division, Grand Junction, CO

Mineralogy of the Cameron Area, Coconino County, Arizona. RME-99; 99 pp.(1964, September)

Uranium deposits at Cameron, Arizona, occur in the Moenkopi Formation and the Shinarump and Petrified Forest members of the Chinle Formation, all of Triassic age, and in the Kayenta Formation of Jurassic age. Commercial production is largely from sandy lenses in the Petrified Forest Member. Primary uranium was deposited in and near carbonaceous fossil logs as uraninite, preceded by marcasite and pyrite and succeeded by galena, greenockite, and pyrite. Calcite and covellite are primary and/or secondary. No conclusion as to the origin of primary uranium was reached. Oxidation produced the following secondary uranium minerals: schoepite; betazippeite; schroeckingerite; phosphuranylite; metatorbernite; meta-autunite; sabugalite; occasional carnotite, tyuyamunite, and metatyuyamunite; uranophane; meta-uranophane; boltwoodite; two unnamed minerals; and at least two minerals not yet identified. These uranium minerals are associated with sulfur, hematite, cobaltian wad, ilsemannite, limonite, atacamite, dolomite, malachite, barite, gypsum, bieberite, halotrichite, alunite, jarosite, metasideronatrite, copiapite, ferrimolybdite, chalcedony, and opal. Overall radioactive equilibrium of deposits and disequilibrium of hand specimens in either direction suggests that uranium was recently redistributed without significant loss despite an almost complete lack of vanadium to fix it. Recency of redistribution is confirmed by the occurrence of uranium minerals in Pleistocene gravel; contrasting disequilibrium in oxidized logs and surrounding halos; discovery, in only slightly lower levels, of unoxidized logs in equilibrium; and results of radiochemical

equilibrium studies indicating ages of 4,500 to 9,000 years for secondary uranium concentrations. So-called bleaching, used as an ore guide, is due chiefly to oxidation products of sulfide deposits. Actual bleaching of clay by acid sulfate solutions from oxidizing sulfides also occurs, accompanied by alteration of montmorillonite to illite and possibly to kaolinite. Positive correlations between elements and uranium found by previous investigators are confirmed, and some are indicated by certain minerals: calcium by gypsum; manganese by wad; molybdenum by ilsemannite; copper by malachite and wad; cobalt by bieberite and wad; nickel by bieberite and wad; lead by galena; and cadmium by greenockite. Negative correlation of aluminum and titanium with uranium indicates less clay in ore zones. Usefulness of secondary minerals and bleaching of clay as ore guides results from redistribution of their constituent elements by the same acid sulfate solutions which redistributed uranium. (Auth)

458
Finkelman, R.B., and H. Klemic; USGS, Reston, VA

Brannerite from the Penn Haven Junction Uranium Occurrence, Carbon County, Pennsylvania. Journal of Research of the USGS 4(6):715-716.(1976, November)

Thorium-free brannerite has been identified in Upper Devonian uraniferous sandstone from Penn Haven Junction, Carbon County, Pennsylvania. The brannerite was located by a variation of the "Lexan" technique and is associated with galena, uraninite, and clausthalite. The angular thorium-free nature of the brannerite suggests that it formed by metamorphism of uranium saturated leucoxene. As a result of the metamorphism, some uranium may be in less soluble minerals than those found in the uranium deposits of the Western United States. For this reason, in-place leaching of the uranium may be impractical. (Auth)

459
Leo, G.W.; USGS, Menlo Park, CA

Autunite from Mt. Spokane, Washington. American Mineralogist 45:99-128.(1960, January)

Near Mt. Spokane, Washington, coarsely crystalline autunite is developed in vugs, fractures, and shear zones in granitic rock. With the exception of dispersed submicroscopic uraninite particles, autunite is the only ore mineral in the deposits. A study of associated granitic rocks reveals that apatite, the most abundant accessory constituent, has been preferentially leached and corroded in mineralized zones, suggesting that it may have provided a source of lime and phosphate for the formation of autunite. Leaching may have been affected partly by meteoric water, but more probably was due to the action of ascending connate solutions that may also have carried uranium from unoxidized, as yet undiscovered deposits at depth. Autunite from the Daybreak Mine has been studied optically, chemically, and by x-ray diffraction. The autunite is commonly zoned from light-yellow margins to dark green or black cores, and autunite from the inner zone has a higher specific gravity and higher refractive index than peripheral light material. X-ray powder diffraction patterns of dark and light meta-autunite formed from this autunite show no significant differences in the "d" spacings; however, diffraction patterns of nine zoned samples each show uraninite to be present in the dark, and absent from the light, phase. UO2 and UO3 determinations range from 0.66-0.70 percent and 57.9-58.0 percent, respectively, for light autunite, whereas dark autunite shows a range (in seven determinations) of UO2 from 1.2 and 4.0 percent, and UO3 from 55.1 to 58.8 percent. The wide range of UO2 values in dark autunite is tentatively attributed to nonuniform distribution of discrete uraninite particles, which may also account for the dark color and higher density. Thermogravimetric and differential thermal analyses (DTA) of autunite suggest discrete water losses at about 90 degrees, 145 degrees, and 220 degrees C. The first water loss probably represents dehydration to meta-autunite II, also recognizable by marked changes in optical properties and the x-ray diffraction pattern. The form of the DTA curve above 90 degrees C resembles that of montmorillonite, suggesting that the dehydrations at about 145 degrees C and 220 degrees C may involve interlayer water as in montmorillonites, and the analogy with montmorillonite is further indicated by x-ray patterns of meta-autunite II heated just above these temperatures. Autunite heated to red heat shows a diffraction pattern distinct from all others. The cation exchange capacity of autunite, about 2.5 milliequivalents per 100 grams, is substantially lower than that previously reported for artificial material. (Auth)

460
Reynolds, R.L.; USGS, Denver, CO

Magnetic Titanohematite Minerals in Uranium-Bearing Sandstones. USGS Open-File Report 77-355; 21 pp.(1977)

Detrital titanohematite minerals have been identified by thermo-magnetic, microscopic, and X-ray diffraction analysis in six uranium-bearing sandstones. Many of the titanohematites are ferrimagnetic and, therefore, are considered to be important in contributing to the permanent magnetization of the sediments in which they are found. The significance of magnetic titanohematite is further amplified by the observation that magnetite is depleted more readily than titanohematite under the geochemical conditions that control the concentration of uranium in these rocks. The presence of titanohematite, in addition to that of magnetite, should be considered in interpreting data of magnetic surveys of uranium deposits in these sandstones. (A 'h)(MLB)

461
Strel'tsov, V.A., V.A. Boronikhin, and A.I. Tishkin;

The Composition of Uraninite from Pegmatite and Uranium-Molybdenum Deposits. Soviet Journal of Atomic Energy 37(1):1043-1051.(1975, January)

Uraninite composition from a pegmatitic and uranium-molybdenum deposit was studied. The uraninite from both deposits contained not only lead, but also uniformly distributed calcium and iron. Thorium and the rare earth elements, which are also distributed uniformly, are characteristic of high-temperature uraninite. Zirconium was detected in the mineral from both deposits, and was found to be due to zircon inclusions in the uraninite. The ancient high-temperature uraninites differed from the younger medium-temperature uraninites by having higher lead contents and lower calcium contents. The differences in lead contents are due to the different ages of the minerals, but the lower calcium content of the high-temperature uraninite does not agree with experimental data on the effect of temperature on the solubility of calcium oxide in uranium oxide. The discrepancy is due to the migration of calcium from uraninite when the minerals of uraninite-containing pyroxene-feldspathic veins are replaced by quartz. All evidence indicates a change in the composition of uraninite with time, not only as a result of nuclear reactions of radioactive elements, but also as a result of the superimposition of more recent hydrothermal processes. (JMT)

462
Weeks, A.D.; USGS, Washington, DC

Mineralogy and Oxidation of the Colorado Plateau Uranium Ores. Peaceful Uses of Atomic Energy, Proceedings of the 2nd International Conference, Geneva, August 8-20, 1955. United Nations, Vol. 6, Geology of Uranium and Thorium, (pp. 525-529), 825 pp.; USGS Professional Paper 300; Contributions to the Geology of Uranium and Thorium, L.R. Page, H.E. Stocking, and H.B. Smith (Comps.), (pp. 187-1933), 739 pp.(1956)

The chief production of Colorado Plateau uranium ores has been from shallow mines in carnotite ore and deep mining penetrating black unoxidized ore. The ores range from highly vanadiferous to nonvanadiferous uranium ores containing not more than trace amounts of vanadium. Chemical, mineralogic, and geologic evidence indicates that the carnotite ores have been derived from progressive oxidation of primary black vanadium-uranium ores. The primary ores contain uranium in uraninite and coffinite and vanadium in montroseite and roscoelite. Minor amounts of copper, lead, iron, and iron sulfides are common. As oxidation begins, montroseite alters to paramontroseite and to another undescribed vanadium oxide. These in turn are reduced chiefly by the corvusite group of minerals. The primary uranium minerals oxidize and combine with vanadium to form rauvite. As oxidation progresses, carnotite and tyuyamunite form from rauvite. The closely related minerals containing vanadium (IV and V) of the corvusite stage of oxidation are replaced by vanadium (V) minerals. The specific ones formed depend closely on pH of the solutions, presence of certain cations to combine with vanadium, and several other factors. Vanadium fixes all available uranium in uranyl vanadates, and the excess vanadium may form hydrated pentoxide, or more commonly, it combines with calcium, sodium, potassium, magnesium, aluminum, iron, or copper to form many vanadate minerals. The carnotite is remarkably stable, thus fixing the uranium very effectively. The nonvanadiferous uranium ores differ notably from the vanadiferous, because oxidation of uraninite produces more kinds of

secondary yellow and greenish-yellow uranyl minerals, such as hydrated oxides, carbonates, sulfates, phosphates, arsenates, and silicates. These secondary minerals are not as stable and therefore do not form large oxidized deposits as does carnotite. (Auth)(MLB)

AUTHOR INDEX

AUTHOR INDEX

AUTHOR INDEX

AUTHOR INDEX

AUTHOR INDEX

AUTHOR INDEX

AUTHOR INDEX

AUTHOR INDEX

AUTHOR INDEX

AUTHOR INDEX

AUTHOR INDEX

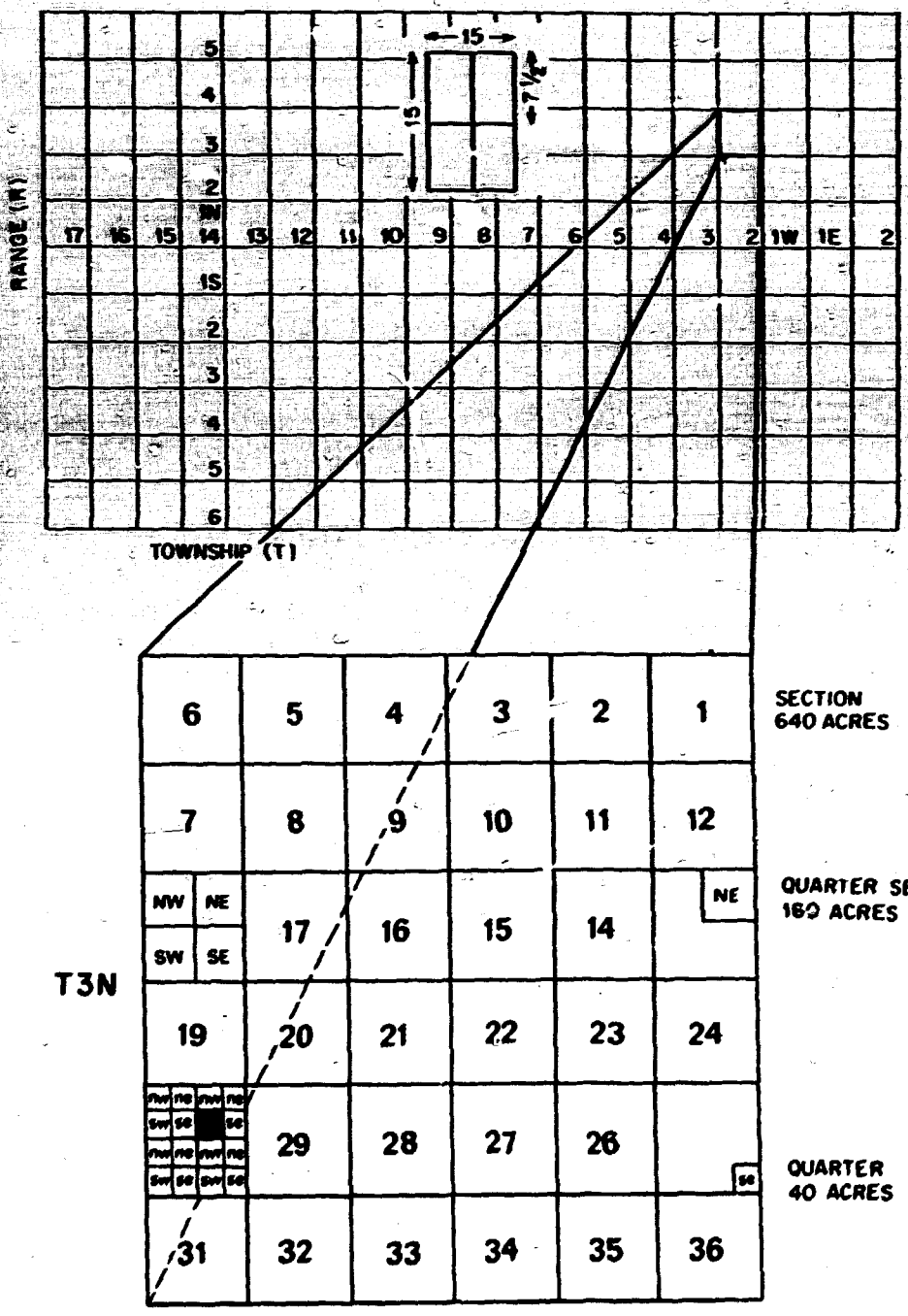
AUTHOR INDEX

AUTHOR INDEX

GEOGRAPHIC LOCATION INDEX

All geographic locations in the United States are indexed by state, and may be followed by county, city, township, range, section, and 7½ or 15 minute quadrangle or combinations of the above. The following illustration shows township, range, section, and 7½ and 15 minute quadrangles.

ORNL-DWG 77-20886



THE SHADED AREA IS IDENTIFIED AS:
T3N, R2W, SEC. 30, NE 1/4, SW 1/4

GEOGRAPHIC LOCATION

GEOGRAPHIC LOCATION

GEOGRAPHIC LOCATION

GEOGRAPHIC LOCATION

GEOGRAPHIC LOCATION

GEOGRAPHIC LOCATION

GEOGRAPHIC LOCATION

GEOGRAPHIC LOCATION

GEOGRAPHIC LOCATION

GEOGRAPHIC LOCATION

GEOGRAPHIC LOCATION

GEOGRAPHIC LOCATION

GEOGRAPHIC LOCATION

GEOGRAPHIC LOCATION

GEOFORMATIONAL FEATURE INDEX

Geologic formations, mines, claims, districts, lakes, rivers, mountains, and other regional structures presented in the reports are indexed.

GEOFORMATIONAL FEATURE

GEOFORMATIONAL FEATURE

GEOFORMATIONAL FEATURE

GEOFORMATIONAL FEATURE

GEOFORMATIONAL FEATURE

GEOFORMATIONAL FEATURE

GEOFORMATIONAL FEATURE

GEOFORMATIONAL FEATURE

GEOFORMATIONAL FEATURE

GEOFORMATIONAL FEATURE

GEOFORMATIONAL FEATURE

GEOFORMATIONAL FEATURE

GEOFORMATIONAL FEATURE

GEOFORMATIONAL FEATURE

GEOFORMATIONAL FEATURE

GEOFORMATIONAL FEATURE

GEOFORMATIONAL FEATURE

GEOFORMATIONAL FEATURE

GEOFORMATIONAL FEATURE

GEOFORMATIONAL FEATURE

GEOFORMATIONAL FEATURE

GEOFORMATIONAL FEATURE

GEOFORMATIONAL FEATURE

GEOFORMATIONAL FEATURE

KEYWORD INDEX

KEYWORD INDEX

KEYWORD INDEX

KEYWORD INDEX

KEYWORD INDEX

KEYWORD INDEX

KEYWORD INDEX

KEYWORD INDEX

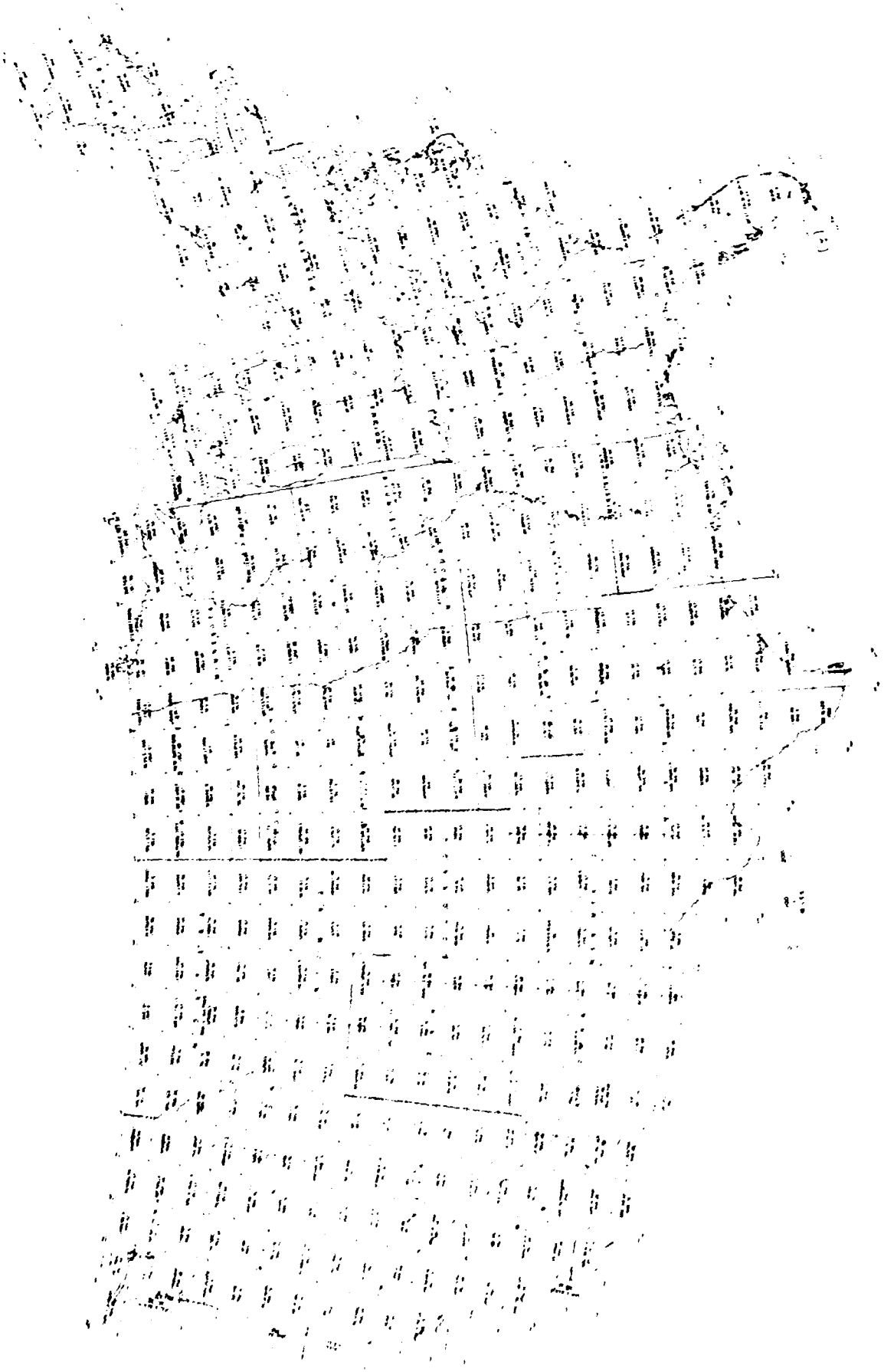
KEYWORD INDEX

KEYWORD INDEX

KEYWORD INDEX

KEYWORD INDEX

KEYWORD INDEX



QUADRANGLE NAME

QUADRANGLE NAME

QUADRANGLE NAME

QUADRANGLE NAME

QUADRANGLE NAME

QUADRANGLE NAME

TAXONOMIC NAME INDEX