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GEOLOGICAL AND GEOCHEMICAL ASPECTS OF URANIUM DEPOSITS

A Selected, Annotated Bibliography—Vol. 4

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Information Division

GEOLOGICAL AND GEOCHEMICAL ASPECTS OF URANIUM DEPOSITS A SELECTED, ANNOTATED BIBLIOGRAPHY

Volume 4

Compiled and edited by

J. M. Thomas, P. A. Garland, M. B. White, and E. W. Daniel

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

Sponsored by the
Grand Junction Office
of the
Department of Energy

Date Published: September 1980

Prepared by the
OAK RIDGE NATIONAL LABORATORY
Oak Ridge, Tennessee 37830
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DEPARTMENT OF ENERGY

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ABSTRACT

This bibliography, a compilation of 464 references, is the fourth in a series compiled from the National Uranium Resource Evaluation (NURE) Bibliographic Data Base. This data base was created for the Grand Junction Office of the Department of Energy's National Uranium Resource Evaluation Project by the Ecological Sciences Information Center, Oak Ridge National Laboratory. The references in the bibliography are arranged by subject category: (1) Geochemistry, (2) Exploration, (3) Mineralogy, (4) Genesis of Deposits, (5) Geology of Deposits, (6) Uranium Industry, (7) Geology of Potential Uranium-Bearing Areas, and (8) Reserves and Resources. The references are indexed by author, geographic location, quadrangle name, geoformational feature, and keyword.

PREFACE

This bibliography of 464 indexed and abstracted references is the fourth in a series of bibliographies produced from the National Uranium Resource Evaluation (NURE) Bibliographic Data Base. The data base was created and maintained by the Ecological Sciences Information Center (ESIC) of the Oak Ridge National Laboratory as information support to the National Uranium Resource Evaluation Project of the Grand Junction Office of the Department of Energy (DOE). In addition to the NURE Bibliographic File, ESIC created and maintains six other data bases for the Grand Junction Office of DOE: Uranium Mines Files, Quadrangle File, Contractor's Report File, Geounits File, Reference File, and Numeric File.

The literature is indexed by subject categories: (1) Geochemistry, (2) Exploration, (3) Mineralogy, (4) Genesis of Deposits, (5) Geology of Deposits, (6) Uranium Industry, (7) Geology of Potential Uranium-Bearing Areas, and (8) Reserves and Resources. Indexes to assist in finding pertinent references are: author, geographic location, quadrangle name, geoformational feature, and keyword. Geographic information is presented by state, county, and/or country if foreign. The study areas are categorized into one-degree by two-degree National Topographic Map Series quadrangles. Geologic formations, mines, claims, rivers, and regional structures located within the study site are listed if they are applicable to the research. All references in this bibliography are contained in the NURE Bibliographic Data Base and are 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:

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ACKNOWLEDGMENTS

F. M. Eckerson of the Grand Junction Office of the Department of Energy provided assistance and guidance in the establishment and compilation of the National Uranium Resource Evaluation data bases. The staff of the Information Sciences and Operations Department, Information Center Complex, Oak Ridge National Laboratory, were responsible for the computer production of this bibliography. This document was reviewed for its content by Mary Moran and Nancy Vaughan.

SAMPLE REFERENCE

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

A EXPLORATION

B 231

C D Price, V.; Jones, P. L., Savannah River Laboratory, Analytical Chemistry Division, Aiken, SC

E Orientation Study Data Release VI: Leesville, South Carolina, Area
F G GJBX-61(78); DPST-78-141-1; 39 pp. (1978, March)

H Water and stream sediment samples were collected from the
upper Coastal Plain, Modoc Fault Zone, Kiokee Belt, and the
Carolina Slate Belt. Currings were collected from water
wells being drilled in the area. This report includes sample
locality maps, uranium distribution maps, tables of water
quality and field measurement data, and tables of uranium
I and other elemental concentrations. (PAG)

J This paper presents only raw data. Field data are presented in two parts: Tables 1 and 2 contain a record of site description data and Tables 3 and 4 contain a listing a field analytical data.

<1>
Texas Instruments Incorporated, Dallas, TX

Study of Airborne Gamma-Ray Spectrometer Data Procedures, Casper Quadrangle, Wyoming.
GJBX-88(88); 158 pp. (1977, October)

A comprehensive study of the aerial gamma-ray spectrometer survey data in the Casper quadrangle, Wyoming has resulted in an improved understanding of the nature of uraniferous provinces and their radiometric characteristics. The survey data were reprocessed to produce conventional radiometric anomaly maps, contour maps of absolute values and significance levels, and stacked profiles of absolute values and significance levels. The resulting gamma-ray data displays were examined in conjunction with the uranium occurrences, geology, surface geochemical samples, LANDSAT imagery, and other published data to establish their inter-relationships and develop more appropriate data collection, analysis and interpretation approaches for the NURE National Aerial Radiometric Reconnaissance Survey. An improved statistical analysis of eU, eU/eTh and eU/K anomaly maps was developed to define uranium anomalies which are both statistically and geochemically significant. Gamma-ray statistical summary data were applied to characterize broad uraniferous geochemical provinces and these data are suggested as a means of relating the gamma-ray data to uranium potential. Contour maps were demonstrated to be useful in displaying gamma-ray data and in defining uraniferous metallogenic provinces. Significance level contour maps were better than absolute values maps in this application. The gamma-ray data show uranium depletion in mapped altered areas associated with the Gas Hills and Shirley Basin districts indicating that the data may be used to search for possible uranium sources for roll-type deposits. Significance factor stacked profiles were easily interpreted than were conventional radiometric stacked profiles, and provide a better low-level anomaly determination to outline uraniferous provinces. Both types of profiles should be studied together for maximum interpretive information. Operational parameter studies indicated that flight-line spacing should be commensurate with the size of the target sought. The data collection period should be designed to detect the smallest target that can be practically resolved along the flight line. Sutides of 1) factors affecting data accuracy and precision, 2) advantages and disadvantages of digital filtering, 3) data clustering and pattern recognition, 4) surface geochemical data, and 5) data collection parameters have resulted in clarification of some problems and have suggested procedural modifications. (Auth) (PAG)

Volume 1 is the narrative report and Volume 2 contains 32 maps, 72 profiles, and 43 histograms.

<2>
Alekperov, R.A., and G. Kh. Efendiev, Academy of Sciences, Institute of Chemistry, Azervaijan, USSR

On the Uranium Content in Petroleum.
Geochemistry 6:621-627. (1959)

The uranium content of some Azerbaijanian petroleum deposits bound in different Tertiary sediments was determined. The uranium content was determined by luminescence of the petroleum ash. Uranium was found to be a component in all the petroleums studied with the concentration varying from 0.0001 to 0.05 percent in the ash or from 1 x 10(E-7) to 5 x 10(E-3) g/l of petroleum. The uranium content and the ash content of the petroleums were inversely related indicating a correlation between uranium content and the organic petroleum components. The character of uranium distribution in the petroleum-sheet waters system depends on the chemical composition of the latter. Equilibrium always shifted towards the petroleum, but it was more pronounced in the case of hard waters. It was established that the decrease of the uranium content, being extracted by petroleum from artificial solutions, is in conformity with the following salt series contained in the solutions: $CaCl2$ - $MgCl2$ - $NaHCO3$.
(Auth) (JST)

<3>
Alekseev, F.A., V.I. Ermakov, and V.A. Filonov, Academy of Sciences, Petroleum Institute, Moscow, USSR

Radioactive Elements in Oil Field Waters.
Geochemistry 7:806-814. (1958)

The concentration and distribution of uranium and radium in waters of oil fields and in rocks related to reef and salt dome structures was studied. For all types of fields similar radium concentrations (n x 10(E-10) g/l) and a low uranium content, rarely exceeding 1.0 x 10(E-7) g/l, were noted. This ratio was considerably higher than the equilibrium ratio in the radium concentration in bed waters with increasing distance from the oil fields. A decrease of radium content in the upper water-bearing horizons with a relative uranium increase was observed. These peculiarities in the radium and uranium contents in waters of oil fields are due to the specific geochemical conditions typical to oil fields. (Auth) (JST)

<4>
Andreyev, P.F., I.V. Andreyeva, and E.N. Rogozina

Reactions of Uranyl Salts with the Components of Plant Tissue and Some of Their Derivatives.
Geochemistry (4):359-364. (1962)

Absorption of uranium from uranyl salts in aqueous solution by cellulose, lignin, wood, and oxidation products of cellulose (oxycellulose, acetyl cellulose, carboxyl-methyl-cellulose, and nitrocellulose) were investigated as a function of concentration and pH. One liter of uranyl nitrate solution with a concentration of 1 x 10(E-2) g/l was passed through the samples at 2-3 ml/min and at pH's of 2.9-9.3. Absorptivities averaged 0.01 g/g; the highest values were from oxycellulose and wood flour (85-95 percent and 100 percent, respectively), the lowest from cellulose (wood and cotton) and acetyl cellulose (74-93 percent, 20-93 percent, and 74-90 percent extraction, respectively). Best results were obtained near pH 5. Part of the absorbed uranium is bound by carboxyl groups; evidence from similar Mo and Pb experiments confirms that most of the absorption is by formation of oxonium complexes, rather than ion exchange or physical adsorption. It is suggested that living plants must possess a defense mechanism against accumulation of uranium, since uranium is essentially absent from their tissues, even when growing in high-uranium soils. (LKH)

<5>

GEOCHEMISTRY

<5>
Arshavskaya, N.I., I.G. Berzina, and E.A. Lyubimova, Academy of Sciences, Institute of the Physics of the Earth, Moscow, USSR; All-Union Institute of Nuclear Geophysics and Geochemistry, Moscow, USSR

Geochemical and Geothermal Data from the Drill Hole of the Pechenga and Pikolatvinsk Regions. Geochemistry International 9(5):764-771. (1972)

The concentration of uranium was determined in the cores of gabbroids and gneisses from drill holes in the Pechenga and Pikolatvinsk regions of the Kola Peninsula. Fission track analysis was used in the determination. Radioelement contents were used to calculate the quantity of radiogenic heat generated in the earth's crust in the two regions of the Precambrian Baltic shield. Heat flow from the crust is only 3.37-12.56 mW/m(E+2) (0.2-0.3 HFU). This indicates that a considerable quantity of heat is generated in the continental upper mantle underlying the two regions. (Auth) (JHT)

<6>
Augustithis, S.S., Institute of Petrogenesis and Geochemistry, Athens, Greece

On the Phenomenology and Geochemistry of Differential Leaching and Element Agglutination Processes. Chemical Geology 2:311-329. (1967)

Uranium containing minerals are often susceptible to differential leaching with a preferential mobilization of certain elements over others under alteration due to hydration. X-ray fluorescent spectroanalyses of unaffected and altered margins of a U, Y niobate from Harrar, Ethiopia showed that U and Nb are relatively more mobile than Y. However, the comparison of U/Th ratios was difficult to assess because of the relatively small amounts of Th present. Additional comparisons of X-ray fluorescent spectroanalyses of unaffected and altered marginal zones of uraninite from Gordonia, South Africa, gave U/Y ratios of 22/1, 10/1, and 5/1 for unaffected uraninite, the black margin of alteration, and the yellow margin of alteration, respectively. U/Th ratios were 10/1, 8/1, and 3/1 respectively. These results were interpreted as indicating a relatively greater mobilization - leaching out - of U over Y and Th. It is suggested that the relatively greater leaching out of U and Nb over Y and Th is due to the fact that U and Nb both possess two different valencies and are thus more mobile under hydration processes in comparison to Y and Th, each of which possesses only one valency. (JHT)

<7>
Baranov, V.I., and N.A. Titayeva, Moscow State University, Department of Geology, Division of Geochemistry, Moscow, USSR

Uranium, Thorium, Radium and Ionium Content in the Quaternary Deposits of the Lena River Valley. Geochemistry 2:121-126. (1961)

Twenty-five samples of peats, bottom muds, and loams from a Siberian permafrost region were analyzed for uranium, thorium, ionium, and radium. Uranium concentrations ranged from 1.6 to 15.0 ppm, thorium from 1 to 14 ppm, ionium from 0.5 to 5.5 ppm, and radium from 0.3 to 3.9 ppm. The investigation of the unconsolidated sediments in the middle course of the Lena River shows that in loams and muds containing less than 10 percent humus the content of uranium, thorium, ionium, and radium is near the average content in sedimentary rocks and soils and that in all samples, the radioactive equilibrium between uranium and radium is well preserved and the equilibrium between uranium and ionium somewhat less so. The average Th/U ratio in the sediments was 4. In the sediments containing plant debris (humus) in excess of 10 percent, there is a noticeable enrichment in uranium and impoverishment in thorium, ionium and radium. In these sediments, the equilibrium between uranium and its daughter products is greatly disturbed and the Th/U ratio is reduced to 0.5. (JHT)

<8>
Baranov, V.I., Le-Tien Tu, and V.L. Korobkov, Moscow State University, Department of Geochemistry and Radiochemistry, Moscow, USSR

Geochemistry of Uranium and Thorium in the Granitic Rocks of the Kyzyltau Massif (Central Kazakhstan), Part 2. Modes of Occurrence of Radioactive Elements in Granitic Rocks. Geochemistry 5:469-483. (1962)

The distribution of radioactive elements in minerals from granites of the Kyzyltau massif was studied by autoradiographic methods using thin sections and grain mounts. It was found that in the course of magmatic differentiation, the content of thorium gradually diminishes, while uranium accumulates in the late differentiates. There was an intimate relation between the content of uranium, and possibly thorium, in the rocks and its constituent minerals. These minerals were divided into three groups: light-colored rock-forming minerals (quartz, potassium feldspars, and plagioclases), accessory minerals, and biotite. The variation of uranium concentrations in samples of granites taken from the same intrusive phase was found to be determined entirely by variation in the uranium content in accessory minerals and the content of these minerals in the rocks. The radioactivity of biotite in the granites was due primarily to inclusions of accessory minerals. Whether the majority of uranium in granitic rocks occurs in the essential or accessory minerals was determined by the conditions of formation of the rocks, particularly by the rate of crystallization of the parent magma. Besides the primary distribution of uranium that dates back to the formation of the rocks, there were also modes of occurrence of uranium which characterize its behavior during secondary processes such as autometamorphism and hydrothermal alteration. The study showed the principal causes of irregular distribution of uranium in the Kyzyltau granites were autometamorphism and undisturbed crystallization of the magma. (JHT)

GEOCHEMISTRY

<9>
Baturin, G.N., Academy of Sciences, Institute of Oceanology, Moscow, USSR

Geochemistry of Uranium in the Baltic. Geochemistry International 5(3):344-348. (1968)

The uranium content in Baltic Sea sediments ranges from 1 to 4 ppm in inshore coarse-grained sediments to 5 to 20 ppm in deep-water clayey sediments. Distribution of uranium in the Baltic sediments is of the ordered type with a distinct pelagic maximum. The distribution and content of organic matter control the uranium content and distribution in the sediments. Hydrogen sulfide occurs only locally and sporadically in the Baltic and, as such, is not a principal factor in the accumulation of uranium in this basin. (JMT)

<10>
Baturin, G.N., A.V. Kochenov, and Yu.M. Senin, Academy of Sciences, Institute of Oceanology, Moscow, USSR

Uranium Concentration in Recent Ocean Sediments in Zones of Rising Currents. Geochemistry International 8(2):281-286. (1971)

Recent sediments around continental coasts have uranium concentrations of about 10 ppm, several times those in deepwater oceanic sediments. The biogenic and diagenetic phosphates in these sediments contain 10-100 ppm uranium. In both cases, the uranium accumulated is extracted from sea water, and this extraction is comparatively rapid from ocean water on the ocean shelf in upwelling regions. This process is responsible for the high contents of organic carbon and phosphorous in the shelf sediments, which in turn arise from the high biological productivity of the shelf waters. Syngenetic accumulation of uranium is produced by organic matter and by biogenic and diagenetic phosphates. (JMT)

<11>
Baturin, G.N., and A.K. Kochenov, Academy of Sciences, Institute of Oceanology, Moscow, USSR

Uranium Content of Oceanic Phosphorites. Lithology and Mineral Resources 9(1):99-103. (1974, November)

Sea bed phosphorites consist of material of diverse form, composition, and mode of occurrence, among which phosphate grains, concretions, plates, blocks, and phosphated rocks may be distinguished in addition to bone detritus. Phosphorites have characteristically high uranium contents ranging from 5-600 ppm. Most known oceanic phosphorites are of Eocene to Lower Pleistocene age. Recent phosphorite concretions have been found only in the shelves of Southwest Africa and Chile, with the former being the most intensively studied. In these deposits, the uranium content is nonuniform and increases gradually in going from the unconsolidated youngest formations to the lithified formations (from 3.9 ppm to 17-86 ppm). The sediments adjoining the authigenic phosphorite concretions on the shelf of Southwest Africa are enriched in organic carbon (10-20 percent) and with uranium (30-60 ppm). The Eh in the surface layer of these sediments is about 200 mV, the pH is 7.2-7.8, and the uranium content of the water of the mud is several orders of magnitude higher than that of sea water. At reduced pH values the uranyl carbonate complex (the form in which dissolved uranium is present in sea water) becomes unstable and promotes sorption of uranium by phosphates. Phosphorite concretions are diagenetic formations and are formed principally below the water-sediment interface. They therefore extract uranium from the water of the mud and not from the sea water. The intensity of this process depends in particular on the specific surface of the sorbent. (JMT)

<12>
Bell, K.G., USGS, Washington, DC

Uranium and Other Trace Elements in Petroleums and Rock Asphalts. USGS Professional Paper 356-B; 20 pp. (1960)

Uranium is a minor trace-element constituent of petroleums and their natural derivatives. The quantity of uranium in crude oils ranges from none to 5 parts per billion. The average uranium content for all crude oil is established to be about 1 ppb, or about 1/3 that of the average content of sea water. Paraffin-base crude oils have the smallest uranium content. Mixed-base and asphalt-base crude oils contain a slightly greater quantity of uranium and they tend to show a rough positive correlation between specific gravity and uranium content. As a group, the crude oils of the Colorado Plateau and Rocky Mountain regions, both being uraniferous provinces, contain less-than-average quantities of uranium, a condition that is attributed to predominance of paraffinic constituents. The bituminous constituents of rock asphalts contain as much as a few thousand parts per billion of uranium, the average being about 1000 ppb. It is believed that the bitumens extract uranium from the host rocks. There is no evidence that petroleum acts as an ore-forming fluid for uranium. Oil field waters containing dissolved organic substances extracted from petroleum and hydrogen sulfide, may provide a reducing environment in which uranium brought in by ground water or hydrothermal solutions may be precipitated at the interface of the solutions. Crude oil is not a practical source material for uranium, and the total uranium content of crude oil reserves of the United States does not exceed 5 tons. The bitumens of the rock asphalt deposits of the United States contain several hundred tons of uranium, but, because these bitumens are dispersed in several billion tons of rock, they are not practical source materials for uranium. (Auth) (JMT)

GEOCHEMISTRY

<13>
Bell, K.G., C. Goodman, and W.L. Whitehead,
United States Gypsum Company, Chicago, IL;
Massachusetts Institute of Technology, Cambridge,
MA

Radioactivity of Sedimentary Rocks and Associated Petroleum. AAPG Bulletin 24(9):1529-1547. (1940, September)

Determinations of the radioactivity of 21 sedimentary rocks and 7 associated crude oils were made. The specimens consisted of cuttings and cores from wells in the Bartlesville, Cromwell, Frio, Woodbine, and Viola-Simpson formations. Considerable variability in radioactivity was found in the sandstones and limestones. The shales were uniform. Apparently, discrete mineral particles in sandstone and impurities in limestone account for their occasional high radioactivity. The radon content of the crude oils was in one sample 38 times the amount in equilibrium with the radium present. The average for the oils was 10 times. These results corroborate the inferences of former investigators that radon tends to concentrate in crude oils. Maximum radon content and maximum ratio of radon to radium were found in petroleum produced from a permeable, Oligocene sandstone of high radioactivity. The amounts of radioactivity found in these crude oils are quantitatively sufficient to cause appreciable cracking by alpha radiation during geologic time. These reactions, together with subsequent hydrogenation, may account for important changes in petroleum. The hypothesis would also explain the presence of hydrogen in some natural gases. The hydrogen content of soil gases is suggested as a possible method of geochemical prospecting for oil fields. (JMT)

<14>
Berthelin, J., G Belgy, and R. Magne, Centre de Pedologie Biologique du C.N.R.S.,
Vandoeuvre-les-Nancy, France

Some Aspects of the Mechanism of Solubilization and Insolubilization of Uranium from Granites by Heterotrophic Microorganisms. (1977)

In batch cultures, complex microflora from granitic mountain mass, promoted solubilization of U in presence of amino-acids as sole source of carbon and energy. Solubilized U amounted up to 100 mg U/1 in presence of microorganisms but was less than 35 mg U/1 in absence of microorganisms (sterile controls). Microflora involved contained different strains of bacteria, PSEUDOMONAS FLUORESCENS, P. PUTIDA, ACHROMOBACTER, BACTERIUM, GAFFKYA or PEPTOCOCCUS. In experimental design of factorial type with semi-continuous flow devices, the activity of different microflora from known forest soil was compared. Microflora specifically withstanding partial sterilization and comprising different PSEUDOMONAS BACILLUS LICHENIFORMIS, B. CEREUS, B. LENTUS, B. POLYMYXA, B. MEGATERIUM, plus one or two unidentified yeasts promoted significantly microbial solubilization of U by synthesis of complexing agents with high complexing capacity for Al and Fe, but lower complexing capacity for U. But anaerobic microflora induced by waterlogging was much less active as compared by solubilization with control microflora. From the comparison of the different strains involved, PSEUDOMONAS appeared to be the most active. In presence of an "organo-uranyl" solution, obtained by adding glutamic or aspartic acids to uranium ore in sterile conditions, different bacteria originating from samples of granitic mountains mass could grow: ACHROMOBACTER, BREVIBACTERIUM, ACINETOBACTER, GAFFKYA or PEPTOCOCCUS, PSEUDOMONAS, showing that such microorganisms could contribute to U deposition by metabolising organo-uranium compounds. Leaching and ecological implications of such processes are discussed. (Auth)

<15>
Bertine, K.K., L.H. Chan, and K.K. Turekian, Yale University, Department of Geology and Geophysics, New Haven, CT

Uranium Determinations in Deep-Sea Sediments and Natural Waters Using Fission Tracks. Geochimica et Cosmochimica Acta 34:641-648. (1970)

Uranium determinations by induced fission track analysis were made utilizing a discharge counter instead of visual counting. Sediments, rocks, freeze-dried river salts (with Na2CO3 carrier) and one freeze-dried sea salt were analyzed by this technique. Comparisons with samples whose uranium concentrations were determined independently indicate that the method is accurate. The uranium concentration in deep-sea sediments varies widely with oceanic depth and depth in the core ranging from 0.5-40 ppm uranium on a calcium carbonate-free basis. Seventeen river water samples ranged from less than 0.01 to 1.2 ppb with an average value of 0.27 ppb. (Auth) (JMT)

<16>
Bradbury, J.C., M.E. Ostrom, and L.D. McVicker, Illinois Geological Survey, Urbana, IL

Preliminary Report on Uranium in Hardin County, Illinois. Illinois Geological Survey Circular 200; 21 pp. (1955)

Tests of about 200 samples taken from Hicks Dome in Hardin County, Illinois and throughout the county suggest that the residual clays and breccias within the Devonian-New Albany area of the dome are generally more radioactive than samples elsewhere, though there are some exceptions. Samples of fluorspar, zinc and lead ores, and concentrates from these ores have little or no radioactivity as measured by Geiger counter. U3O8 determinations made by chemical procedures on 25 samples having some of the higher uranium equivalent values were all lower than the uranium equivalent values. (Auth) (MBW)

GEOCHEMISTRY

<17>
Cadigan, R.A., USGS, Washington, DC

Geochemical Anomalies and Alteration in the Moenkopi Formation, Skull Creek, Moffat County, Colorado. USGS Professional Paper 761; 21 pp. (1972)

The Triassic Moenkopi Formation is exposed in the scarp encircling Skull Creek anticline in Moffat County, Colorado. The formation contains a thick altered layer of greenish-gray siltstone which is overlain by reddish-brown siltstone in most localities. Metal content of both the red and altered rocks in the Skull Creek area is significantly higher than the geometric mean of metal content of Moenkopi strata in the Colorado Plateau region as a whole. A very thin zone of enrichment at the upper contact of the green altered rock with the overlying red rock contains anomalous amounts of copper (100-5000 ppm) and other metals. Other anomalous occurrences of mineralization and alteration include a copper-uranium deposit in the base of the Jurassic Curtis Formations. Factor analysis of measurements of metal content of the enrichment zone suggest two major events: (1) Invasion of the rocks by metal-bearing solutions and alteration of part of the Moenkopi, and (2) and interaction at the contact between the red rocks which represent an oxidized environment and the green rocks which represent an invading reducing environment. This interaction results in a thin zone of enrichment of leached and redeposited metals - mercury, copper, silver, uranium, and gold - at the geochemical interface. The authors recommend for further geochemical exploration. (JMT)

<18>
Campbell, I.H., and P.R. Kelly, University of Melbourne, School of Earth Sciences, Parkville, Victoria 3052, Australia

The Geochemistry of Loveringite, a Uranium-Rare-Earth-Bearing Accessory Phase from the Jimberlana Intrusion of Western Australia. Mineralogical Magazine 42(322):187-193. (1978, June)

The distribution and geochemistry of loveringite, an accessory Ti, Fe plus or minus Cr oxide containing U and rare-earth elements from the Jimberlana Intrusion was studied. The Jimberlana Intrusion is a layered horizontal pipe-like body containing three layered series: the upper layered series, the lowered layered series, and the marginal layered series. The lowere layered series consists of a repeated macro-rhythmic succession of olivine and bronzite cumulate layers overlain by a thick layer of plagioclase-augite-hypersthene cumulates. The upper layered series is similar but has a granophyric layer (55-57 wt. percent SiO_2, graophyric texture) at the top of the succession. It is thought to be due to a new pulse of magma that was injected into the magma chamber before crystallization of the lower layered series had reached the granophyric stage. Most of the samples used in this study came from the lower layered series, but three samples were included from the granophyric layer of the upper layered series. Loveringite is most abundant in the bronzite cumulates; it is found in trace amounts in early plagioclase-augite-hypersthene cumulates, but is not found in the olivine cumulates or in the late-stage differentiates. Loveringites from the bronzite cumulates have a high Cr content compared with those from the plagioclase-augite-hypersthene cumulates, suggesting intercumulus liquid. The Lanthanide Series rare-earth pattern shows a strong depletion trend from La to Eu, a sharp reversal between Eu and Tb, and a second depletion pattern from Tb to Lu. This pattern suggest that the Lathanide series rare earths are substituting into two sites, one much larger than the other. (JMT)

<19>
Cassou, A.M., J. Connan, M. Correia, and J.J. Orgeval, Societe Nationale des Petroles d'Aquitaine, Centre de Recherches de Pau, Pau, France; National College of Applied Geology and Mine Prospecting, Nancy, France

Chemical Studies and Microscopic Examinations of the Organic Matter in Some Uraniferous Ore Bodies. The Oklo Phenomenon, Proceedings of a Symposium, Libreville, Gabon, June 23-27, 1975. International Atomic Energy Agency, Vienna, Austria, (pp. 195-206). (1975)

Uraniferous ore bodies are often accompanied by considerable concentrations of organic matter. Studies have been made of the organic matter in Francevillian samples from Oklo and in Permian samples from the Lodeve Basin in France. Techniques derived from organic geochemistry and optical microscopy were used. Microscopic examinations were carried out in transmitted and reflected light (natural and fluorescent). For the Lodeve Basin, the uraniferous samples were compared with sterile ones. Their kerogenesis is clearly more advanced and they are without chloroformic extract. Their gaseous hydrocarbons (C1-C6) have a dry-gas composition and their gasoline fractions (C6-C15) contain only light elements (C1-C8). In short, while the sterile samples possess high-quality organic matter whose diagenetic stage is that of oil diagenesis, the radioactive samples are found to be more mature at the gas diagenesis stage. The Oklo samples are similar to the Lodeve uraniferous samples (low concentration of chloroformic extract, gaseous hydrocarbons with a dry-gas composition, gasoline with predominantly light molecules). However, the degree of evolution of their organic matter appears to be higher (reflecting power of the vitrinite and exinite: carbon ratio); moreover, it becomes increasingly high as one approaches the nuclear reactor. From this preliminary study, it would seem that modifications of the organic matter due to irradiation reveal themselves in a distinctly higher degree of evolution. (Auth) (JMT)

<20>

GEOCHEMISTRY

<20>
Chang, C.W., and W.D. Lu, Institute of Nuclear Energy Research, Atomic Energy Council, Lung-tan, Taiwan 325, Republic of China

Determination of U-235/U Isotopic Ratio by Gamma-Ray Spectrometric Method. Nuclear Science Journal 11(1):11-17. (1974, March)

A simple, non-activation gamma-ray spectrometric method for the determination of U-235/U isotopic ratios was studied. The method is based on the proportionality of the specific count rates of the 185 keVgamma-ray from U-235 to the U-235/U isotopic ratios at fixed experimental conditions. The U-235/U isotopic ratios were determined by comparison of the specific count rates of the unknown sample with that of a standard of known U-235/U isotopic ratios. The effects due to uranium self-absorption and the method for the correction were also discussed. The precision of the method is about 3 percent. (Auth)

<21>
Cheney, E.S., and H.L. Jensen

Stable Isotopic Geology of the Gas Hills, Wyoming, Uranium District. Economic Geology 61(1):44-71. (1966)

A sulfur, carbon, and oxygen isotopic study of more than 300 samples has been made of the sandstone-type uranium deposits of the Gas Hills district, Wyoming. The deposits occur as rolls and blankets in the arkosic, low Eocene Wind River Formation located on the southern edge of the Wind River Basin. Pyrite cement associated with uranium mineralization is isotopically similar to the acid soluble sulfides produced by anaerobic bacteria in nearby springs and is significantly lighter and more variable in S 34 composition than undoubted magmatic hydrothermal sulfides. Isotopic analyses of hydrogen sulfide from a neighboring oil field, pyrite in granitic Precambrian cobbles, and groundwater sulfate from the overlying tuffaceous strata are consistent with, but do not prove, the "volcanic leach" hypothesis of origin for the sulfur of the epigenetic pyrite. The very light S 34 composition of pyrite associated with jordisite and coalified wood, and the enrichment of S 34 in selenium bearing pyrite and groundwater sulfate of the host Wind River Formation suggest limited production of hydrogen sulfide, resulting in isotopically heavy supergene sulfides. The extremely light isotopic composition of pyrite associated with jordisite on the leading edges of roll ore bodies is probably caused by oxidation and re-reduction of previously formed biogenic sulfides. Further evidence of a biogenic origin for these deposits is furnished by the carbon isotopic composition of epigenetic calcite cement. The similiarity of the C 13 values of calcite associated with asphalt and calcite associated with coalified wood implies that the anaerobes derived their energy from both. The heavier isotopic composition of most of the other epigenetic calcites suggests some contamination by sedimentary carbonate during calcite precipitation. The study shows that syngenetic-diagenetic and epigenetic deposits of bacterial origin have distinguishable sulfur and carbon isotopic characteristics. The extremely light S 34 composition of sandstone-type uranium deposits is believed to be primarily due to the reduction of fairly light sulfate by anaerobes in an environment that approximates a closed system. Further enrichment in S 32 occurs when these isotopically light sulfides are oxidized to light sulfate which is again reduced to pyrite during the formation of roll ore bodies. (Auth) (JBT)

<22>
Chenoweth, W.L., DOE, Grand Junction, CO

Uranium in Western Colorado. The Mountain Geologist 15(3):89-96. (1978, July)

Uranium deposits in western Colorado occur in rocks of many geologic ages and lithologic types. Bedded, vanadiferous deposits in continental, fluvial sandstones of the Salt Wash Member of the Morrison Formation of Jurassic age are the most important. A cluster of deposits in Mesa, Montrose, and San Miguel Counties comprises the Colorado segment of the Uravan mineral belt, the largest uranium area in Colorado. During the period 1948 through 1976, 15,589,100 tons of ore with an average grade of 0.23 percent U_3O_8 and containing 71,132,400 pounds of uranium oxide (U_3O_8) have been produced from western Colorado. This amounts to 12 percent of the total United States' uranium ore production. In addition, 350,522,000 pounds of vanadium oxide (V_2O_5) have been recovered. The discovered ore reserves and the favorable geology for undiscovered potential resources are expected to maintain western Colorado as a significant source of uranium for years to come. (Auth)

<23>
Cherdyntsev, V.V., U.Kh. Asylbaev, D.P. Orlov, L.I. Shmonin, E.A. Isabaev, and W.B. Kadyrov, Academy of Sciences, Institute of Geology, Moscow, USSR; Kazakh State University, Alma-Ata, USSR

Uranium Isotopes in Nature: Actinium-Radium Ratios in Minerals. Geochemistry 8:700-706. (1961)

The actinium-radium ratio was determined in 34 minerals by means of alpha-ray spectrometry. Variations of the actinium-radium ratio up to Ac/Ra=8 were observed. Altered minerals tended to have the higher Ac/Ra ratios, possibly because of the loss of radium. There was an excess of actinium in other minerals, particularly cassiterites and molybdenites. This was thought to be due in part to radioactive decay. Occurrences of excess uranium 235 were observed in minerals with higher then normal actium contents. (JMT)

GEOCHEMISTRY

<24>
Cherdyntsev, V.V., I.V. Kazachevskii, and E.A. Kuz'mina, Academy of Sciences, Geological Institute, Moscow, USSR

Isotopic Composition of Uranium and Thorium in the Supergene Zone. Geochemistry 3:271-283. (1963)

The ratio of thorium and uranium isotopes in natural waters, fossil bones, soils, and shells of fresh water mollusks at the Molodovo Paleolithic sites and other areas of the Dnestr region was investigated. The waters of the Molodovo sites are of two types. The first type originates from Sarmatian limestones and has a low U 234/U 238 ratio. The second type includes waters with with a gamma of 1.20 to 1.36 that issue from Paleozoic shales. Mineralization of fossil bones in the upper Paleolithic layers was accomplished by waters with low gamma value, and bones in the middle Paleolithic layers were mineralized by waters with high gamma values. The suggestion that uranium migrates so that upper layers are impoverished and lower layers are enriched in uranium was substantiated by the ratios of radioelements in fossil bones from the Molodovo sites. The migration process apparently did not affect the Mousterian layers at Molodovo V site so that the age of 130,000 years for these layers determined from the Io/UX(sub 1) ratio and gamma is close to the correct value. The age of the fossil soil of the lower horizon at Molodovo I is more than 260,000 years. Shells of fresh water mollusks from the terraces of the Dnestr river near Tiraspol showed an intensive migration of radioelements with a large supply of uranium and radium isotopes. (Auth) (JMT)

<25>
Cobb, J.C., and J.L. Kulp, Brookhaven National Laboratory, Chemistry Department, Upton, NY

U-Pb Age of the Chattanooga Shale. Bulletin of the Geological Society of America 71:223-224. (1960, February)

Three samples of the Gassaway Member of the Chattanooga Shale were analyzed by isotopic dilution techniques. The three samples contained 112 ppm, 90.6 ppm, and 68.3 ppm uranium. U 238-Pb 206 ages for the three samples were 350 plus or minus 12-17 million years for two samples and 450 plus or minus 70 million years for the third. Radium measurements on these samples show that it is now in equilibrium with the uranium. This suggests that either alteration is negligible or, the radium is being moved about. It is therefore quite possible that the true age of the Chattanooga Shale is about 350 million years. These data would appear to set a firm minimum age for the Mississippian-Devonian boundary of 350 m.y. (JMT)

<26>
Coppens, R., and A. Bernard, Laboratoire de Radiogeologie de l'E.N.S. de Geologie, Nancy, France; Laboratoire de Metallogenie de l'E.N.S. de Geologie, Nancy, France

Deplacements de l'Uranium dans les Roches Cristallines Application a la Prospection des Depots Uraniferes. Mineralium Deposita 13(2):165-182. (1978)

It is possible to estimate uranium movement in granitic rocks through the variations of fixed to total uranium ratio of these rocks. Some granites exhibit linear relations (r=0.99) between these two variables even for high grades, showing that uranium movement has been limited, if any took place at all. Granites devoid of uraniferous deposits belong in this class. Other granites do not yield such narrow linearity above 10 ppm. This means that once local traps have been saturated, they are not able to retain uranium in response to driving forces such as metamorphism and meteoric leaching. As a result of this leachable uranium may circulatae eventually being concentrated in structural traps within the granitic mother-rock or in the surrounding formations. This occurs in many uraniferous granites in France, and the distinction could be useful in exploration of granitic areas. (Auth) (JMT)

<27>
Cundari, A., J.G.R. Renrad, and A.J.W. Gleadow, University of Melbourne, School of Earth Sciences, Parkville, Victoria 3052, Australia; Chevron Exploration Corporation, Melbourne, Victoria 3000, Australia

Uranium-Potassium Relationship and Apatite Fission Track Ages for a Differentiated Leucitite Suite from New South Wales (Australia). Chemical Geology 22:11-20. (1978)

Detailed analysis of the uranium content and distribution in a differentiated leucitite suite shows that uranium is negatively correlated with potassium and decreases with increasing differentiation. It is found that uranium is preferentially concentrated in the late-crystallized fractions of the lavas, but the uranium concentrations decrease with increasing proportions of these fractions in the bulk rocks. Perovskite strongly partitions uranium from the differentiated liquid and reverses the uranium-enrichment trend calculated from crystal fractionation models. This process may be important in other perovskite-bearing alkalic lavas in the East African Rift, Hawaiian and Roman volcanic provinces. The lavas discussed are related to an unusual mantle source composition in the low velocity zone. (Auth)

<28>
Damon, P.E., University of Arkansas, Institute of Science and Technology, Fayetteville, AR

Radioactivity and Mineralization in Rhyolite Porphyry. Geophysics 15(1):94-101. (1950)

Measurements of the hard gamma radiation from the Precambrian rhyolite porphyry of the Bourbon, Missouri, well core show a direct relationship between mineralization and radioactive content. Low activities are, in general, associated with high mineral density, whereas the mineral density is a function of the magnetite content. The low activities are most probably due to a leaching out of the potassium content. This indicates that gamma-ray well logs should be capable of accurately measuring the location of mineral deposits in potassium rich rock. Potassium analysis of the core is planned by the Missouri Geological Survey. (Auth)

GEOCHEMISTRY

<29>
Darnley, A.G., E.M. Cameron, and K.A. Richardson, Canada Geological Survey, Ottawa, Ontario, Canada

The Federal-Provincial Uranium Reconnaissance Program. Geological Survey of Canada Paper 75-26, (pp. 49-63). (1975)

The overall objectives of the Federal-Provincial Uranium Reconnaissance Program are to provide industry with high quality reconnaissance exploration data to indicate those areas of the country where there is the greatest probability of finding new uranium deposits, and to provide government with nationally systematic data to serve as a base for uranium resource appraisal. The program will involve high sensitivity airborne gamma-ray spectrometry over areas of low relief and some outcrop, required geochemistry in mountainous terrain and in areas with extensive overburden, and special emphasis on hydrogeochemistry in flat-lying sedimentary basins. The administrative arrangements for the program are being modelled as closely as possible upon the Federal-Provincial Aeromagnetic Program which commenced in 1961. The Federal Government, through the Geological Survey of Canada and in consultation with the relevant provincial agencies, will be responsible for designing and administering contracts for the execution of this work which will be undertaken by Canadian contractors. The Geological Survey of Canada will be responsible for conducting limited airborne and ground pilot studies ahead of the contracted operation in order to verify the suitability of particular areas for the available methods, and in order to provide control data. Results from the program will be published as rapidly as they can be compiled. They will be released simultaneously by the Federal and Provincial authorities as has been the practice in the Aeromagnetic Program. (Auth)

Cited as a reference in NURE Contractor Reports.

<30>
Davis, J.D., and J.M. Guilbert, University of Arizona, Department of Geosciences, Tucson, AZ

Distribution of the Radioelements Potassium, Uranium, and Thorium in Selected Porphyry Copper Deposits. Economic Geology 68(2):145-160. (1973, March)

The distribution and zoning of K, U, and Th in the porphyry copper orebodies at Ajo, Mineral Park, and Morenci, Arizona, and at Santa Rita, New Mexico were determined using a truck-mounted gamma-ray spectrometer. Chemical analyses of hand specimens were also performed. Conclusions of this study were that: K shows a zonal distribution in the 4 porphyry copper deposits examined, which is consistent with current alteration models. U and Th may be zonally distributed, but their relationship to established alteration zones is less clear. K highs are generally centrally located in the intrusive mass or ore-forming system. K is more abundant by factors of 1.2-3 in mineralized stocks than in nearby temporally and chemically similar unmineralized stocks. Th and U are not significantly or systematically enriched. The measured anomalies are as valid over undisturbed surfaces as in open pit mines. Supergene enrichment mechanisms do not leach K sufficiently to eradicate K anomalies (Mineral Park and Santa Rita). Radiometric measurement of K is a valid exploration tool in the search for porphyry base metal deposits. U and Th analysis do not appear to be of any consistent value at present. Traverses over porphyry Mo deposits and airborne gamma-ray scintillometry over both porphyry Mo and Cu deposits should be carried out. (LKM)

<31>
Della Valle, R.S., and D.G. Brookins, University of New Mexico, Albuquerque, NM

Geochemical Studies of Grants Mineral Belt, New Mexico. AAPG Bulletin 63(4):687. (1979, April)

Several hundred clay mineral and whole rock samples of ores and barren rocks from the Grants mineral belt have been analyzed by instrumental neutron activation analysis (INAA) and delayed neutron activation analysis (DNAA). The DNAA method allows high precision and accuracy for uranium and thorium determination, whereas the INAA method allows determination of 20 to 30 trace elements. The trace-element data can only be interpreted properly if the clay-mineral fraction is compared directly with whole-rock samples. The INAA data support mineralization of trend ore as due to southeast-flowing solutions; the DNAA determination of uranium suggests that the source of uranium in the Westwater Canyon Member of the Jurassic was not from the overlying Brushy Basin Formation. Local zonation of trace elements, especially the rare earth elements (REE), indicates fixation of many trace elements when uranium mineralization occurred. Thus, REE-depleted, oxidized ground can, with caution, be used for exploration purposes. Vanadium originally precipitated as $V3+$ in chlorites remains in the original sites after oxidation to $V5+$ and is thus also valuable as a pathfinder. Data for antimony suggest that it, too, may be useful. In general, trend-ore deposits are characterized by a high chlorite + illite, illite + illite-montmorillonite, or illite + chlorite + illite-montmorillonite, whereas ore near the redox front may contain primary kaolinite. The REE are concentrated greatly in all types of ore, primary or secondary, and, coupled with uranium haloes, are useful as ore guides. (Auth)

<32>
Dement'yev, V.S., and N.G. Syromyatnikov, Academy of Sciences, Institute of Geological Sciences, Kazakh, USSR

Modes of Occurrence of Thorium Isotopes in Ground Waters. Geochemistry International 2(1):141-147. (1965)

The thorium content of ground waters is highest in waters of low salinity, hardness, and pH, and high organic content. These relationships indicate transport as colloidal suspensions and anionic complexes involving soil acids. Centrifuging the waters causes Th 232 to settle out more rapidly than Th 228 and Th 230. This and the difficulty of dialyzing Th 232 indicates a concentration of radiogenic isotopes in ionic solution and a concentration of Th 232 atoms in suspended particles. (JMT)

<33>
Dickinson, K.A., USGS, Washington, DC

Uranium and Thorium Distribution in Soils and Weathered Bedrock in South Texas. USGS OFR-77-768; 18 pp. (1977)

Uranium and thorium concentrations were measured by delayed neutron-activation for five weathering profiles in southern Texas. Four of the profiles were in the Jackson Group, two in McMullen County and two in Karnes county; one profile was in the Catahoula Tuff in Karnes County. The average uranium concentrations from the five profiles ranged from 2.7 to 17.3 ppm. Thorium contents ranged between 13.0 and 30.0 ppm with the average Th/U ratio ranging between 0.8 and 5.1. The uranium distribution in the soils resembled that of the Sr^{+2} and Ba^{+2} ions; a resemblance that suggested the uranium was transported as UO_2^{+2}. No systematic vertical deposition order, indicated by the layers of maximum concentration, was found. Thorium distribution in the profiles was similar to that of uranium. Since thorium does not form an ion chemically similar to uranium in the oxidizing uranium, this was considered unusual but no explanation was offered. Certain conclusions of importance in uranium exploration were derived from the study. Uranium was leached from the surface in the calichified soil and deposited deeper in the soil, possibly being adsorbed on clinoptilolite or montmorillonite. The data provided from the study support earlier conclusions that the uranium was mobilized during periods of dry-climate weathering. It also suggests that caution should be used in the interpretation of airborne radioactivity measurements, because these measurements are made on near surface soil material, which has suffered the greatest loss of uranium and thorium by leaching. (JMT)

<34>
Dickinson, K.A., USGS, Washington, DC

Uranium Potential of the Texas Coastal Plain. USGS OFR-76-879; 9 pp. (1976)

Uranium potential of the Eocene and younger Texas coastal plain rocks is being evaluated. The uranium areas consist of host rocks from the Whitsett formation (Eocene) of Karnes County, the Oakville sandstone (Miocene) in Live Oak County, and the Catahoula tuff (Miocene) in Duval County, and are the basis for this evaluation. The potential resources are discussed from several aspects: source rock, leaching, movement, host rock, chemical reductant, and preservation. The Catahoula tuff is thought to be the principal source for the uranium; its low uranium content, 3 ppm, and high thorium-to-uranium ratio, 5.6 suggest that uranium has been leached from the formation. Arid climatic conditions at the time of uranium deposition (post Eocene) played a major role. The uranium became mobilized as di- or tri-carbonate ions under oxygenated, mildly alkaline conditions. Uranium-bearing water moved as surface drainage of meteoric water and as ground water through porous rock units and along faults and joints. Fluvial channel deposits were especially important in directing the uranium-bearing water into host rocks. The uranium host rocks (Whitsett, Frio clay, Catahoula and Oakville) are well-sorted permeable sandstone units enclosed in mudstones and claystones, and are deposited in fluvial channels. Autogenic and allogenic reductants influenced deposition in the area; carbonized plant material is an example of the former, dissolved organic matter and petrolic gases are examples of the latter. The dry climate acted as a primary component in preserving the uranium deposits, but a caliche cap present in most of the area restricted leaching of the uranium. There is a much greater potential for large new uranium deposits in the deeper subsurface in south Texas. The conditions for formation are nearly the same as for the present uranium-producing areas in south Texas, except for the depth of ore burial. In the study area, Karnes and Duval Counties contain most of the probable deposits. (MJB)

<35>
Dmitriyev, L.V., and L.L. Leonova, V.I. Vernadskii Institute of Geochemistry and Analytical Chemistry, Moscow, USSR

Uranium and Thorium in the Granitoids of the Kaib Massif (Central Kazakhstan). Geochemistry 8:769-777. (1962)

Uranium and thorium were found to be uniformly distributed in granites of the principal facies of the principal intrusive phase of the Kaib Massif. The average uranium content in these granites was 2.8 ppm and the average thorium content was 24.6 ppm. The Th/U ratio of the principal facies was high running around 8. No correlation could be found between the composition of the rock and its uranium and thorium contents. Uranium was not transported from the central part of the intrusion to the marginal parts, and no enrichment of the marginal parts in uranium occurred because the country rocks contained less uranium than the massif. Enrichment in uranium occurs only in greisenisation or high temperature silicification, where the average uranium content was about 6.5 ppm. (JMT)

<36>
Dodge, F.C.W., USGS, Denver, CO

Trace-Element Contents of Some Plutonic Rocks of the Sierra Nevada Batholith. USGS Bulletin 1314-F; 13 pp. (1972)

Trace element analyses of plutonic rocks of the Sierra Nevada batholith were conducted and the results were given in this report. In general, the average abundance of the elements determined are similar to the average abundances of high-calcium granites of the earth's crust. The large, highly coordinated trace elements are more abundant in Sierra Nevada plutonic rocks than in calc-alkaline circum-Pacific andesites, whereas many other elements are about the same as, or slightly less abundant than in andesites. Lateral changes across the central Sierra Nevada batholith are well defined for beryllium, uranium, thorium, and rubidium, all of which systematically increase eastward. Over six hundred determinations were made on the samples for uranium and thorium content with the ranges running 0.31-29.56 ppm and 0.18-50.12 ppm, respectively. (JMT)

GEOCHEMISTRY

<37>
Dooley, J.R., Jr., C.W. Conwell, P. Berendsen, J.K. Otton, C.T. Pierson, W.D. Hoisington, D.A. Lindsey, and J.N. Rosholt, USGS, Denver, CO

Examples of Uranium Distribution Graphics in Geologic Rock Specimens Illustrated with the Radioluxograph Induced Fission Tracks, and Other Track Methods. USGS Circular 753; Short Papers of the US Geological Survey Uranium-Thorium Symposium, 1977, J.A. Campbell (Ed.), (p. 32), 75 pp. (1977)

Fast photographic film along with the amplification provided by the Radioluxograph can provide autoradiographs which graphically illustrate the distribution of the uranium-series and thorium-series isotopes from sections of geologic specimens in a relatively short time. Radioluxographs of ore-grade material with as little as 1,000 ppm uranium can be made in a fine minutes to a few hours. Detection of sub-ore-grade material containing as little as 10 ppm uranium and thorium can generally be made with the Radioluxograph in several days, but homogeneous distributions require somewhat longer autoradiographic exposure times. This method is best suited for a quick and inexpensive reconnaissance view of the uranium and thorium distribution on a "macro" scale. Induced fission from a nuclear reactor or other high-flux source of neutrons can specifically detect uranium and, to a lesser extent, thorium from the fission tracks produced upon Lexan, mica, and other solid-state particle detectors. After being properly developed by chemical etching the detector serves as a fission-track map which can be viewed under the microscope and compared with the specimen which produced the tracks. Samples that are over-irradiated produce a high concentration of tracks which is visible to the unaided eye, and is somewhat similar to an autoradiographic image. Most reactors can only accomodate sample sections less than 2.5 cm in diameter and are generally used to study low uranium concentrations because of the reactor's capacity to produce high neutron fluxes. Alpha decay from the naturally occurring radioisotopes and other induced nuclear reactions can be recorded on cellulose nitrate and used for "micro" autoradiography if exposure to light and other photographic effects can be avoided. Microscopic examination of alph-particle tracks on these detectors and in nuclear photographic emulsions are almost always required and give better resolution than other "macro" methods of autoradiography. Radioluxographs were made of sawed rock sections and drill cores. Polished sections and uncovered thin sections can be used with induced fission tracks and other alpha track methods as well as with the Radioluxography. Homogeneous distribution of 7 ppm uranium and 11 ppm thorium was found in a tektite with a Radioluxograph. Nonhomogeneous distributions of uranium and thorium are categorized into single accessory minerals; aggregates; concentrations along bedding, vein or fracture fillings; and mineral zoning localizations. High levels of single grain radioactivity dispersed within lower levels of homogeneous or nonhomogeneous radioactivity are best demonstrated with two autoradiographs of different exposure lengths. Semi-quantitative determination of uranium can be made from comparing successive autoradiograph exposures of different time lengths or different neutron flux intensities and quantitative determinations can be made from track counting. (Auth) (JST)

<38>
Dostal, J., S. Capedri, and C. Dupuy, St. Mary's University, Department of Geology, Halifax, Nova Scotia, Canada; Universita di Modena, Instituto di Mineralogia e Petrologia, Italy; U.S.T.L. Department de Geologie, Montpellier, France

Uranium and Potassium in Calc-Alkaline Volcanic Rocks from Sardinia. Lithos 9(3):179-183. (1976)

The uranium content of major rock-forming minerals in a suite of calc-alkaline volcanic rocks from Sardinia is very low and their partition coefficient of U is smaller than 0.1. The values of the partion coefficient of mineral phases decrease from basalt to dacite and, in all rocks, the bulk of U and K is present in the groundmass. This apparent close association between K and U in basic and intermediate rocks probably reflects the fact that most of their rock-forming minerals are relatively inert with respect to both of these elements. (Auth)

<39>
Dyck, W., Canada Geological Survey, Ottawa, Ontario, Canada

The Mobility and Concentration of Uranium and its Decay Products in Temperate Surficial Environments. Uranium Deposits, Their Mineralogy and Origin, Short Course Handbook, Volume 3, M.M. Kimberely (Ed.). University of Toronto Press, Toronto, Canada, Ch. 2, (pp. 57-100), 521 pp. (1978, October)

Uranium is the most abundant element of the uranium decay series, with an average crustal abundance of about 2.6 ppm. Its high mobility in the surficial environment is due to oxidation to the uranyl ion which forms soluble carbonate complexes. Uranium-decay products generally do not form soluble compounds and thus secular disequilibrium of the series is commonly observed. Disequilibrium is almost invariably due to the removal of uranium under oxidizing conditions or uranium addition under reducing conditions. Reestablishment of radioactive equilibrium requires time spans of several half-lives of the daughter products. The stable end products (lead and helium) represent the extremes of mobility of the decay products; lead is relatively immobile and helium is able to escape to outer space. (Auth)

GEOCHEMISTRY

<40>
Dyck, W., R.W. Garrison, G.S. Wells, [illegible] Godoi, Canada Geological Survey, Ottawa, Ontario, Canada

Well Water Uranium Reconnaissance in Eastern Maritime Canada. Geological Survey of Canada Paper 75-1C, (pp. 313-315). (1975)

To test the feasibility of using well waters as a means of tracing U occurrences in the Carboniferous basin of Eastern Canada, a survey of approximately 2000 wells was conducted in 1975. In addition, about 120 well water and 100 stream water and sediment samples were taken from the northern Annapolis Valley (Triassic). An overall sample density of 1/13 sq. km was sought, but in two areas, 665 sq. km between Sackville and Moncton and 390 sq. km near Pugwash, N.S., sampling at 1/6.2 sq. km and 1/2.5 sq. km, respectively, was carried out. Samples were analyzed for U, Rn, O_2, F, Eh, pH, alkalinity, conductivity, NO_3, SO_4, Cl, Ca, K, Na, CH_4, H_2, Cu, Zn, Pb, Fe, and Mn. The survey showed extensivy U and Rn anomalies along the coast of Nova Scotia and New Brunswick between New Glasgow and Cape Tormentine. Values range up to 60 ppb U and 5700 pCi/l Rn, with the highest values near Baie Verte, Pugwash, Chisholm Brook, Fox Harbour, Tatamagouche, and River John; concentrations generally decrease inland. Granitic rocks of the Cobequid may be the source of the ground water U. The survey demonstrates the value of U and Rn as tracers in outlining U mineralization in the Carboniferous basin. As results are studied in more detail other aspects of the regional hydrogeochemistry may be recognized. (LKH)

<41>
Dyck, W., and I.R. Jonasson, Canada Geological Survey, Ottawa, Ontario, Canada

The Nature and Behavior of Gases in Natural Waters. Water Research 11(8):705-711. (1977)

Approximately 800 samples of lake, stream, and U-mine waters were collected from Gatineau Hills, Quebec; Carlsbad Springs, Ontario; Elliot Lake, Ontario; the New Insco copper deposit, Duparquet, Quebec; the Bicroft uranium deposit (abandoned); and the Bancroft, Ontario area, and analyzed for dissolved gases. These included: N_2, He, Ne, H_2, O_2, H_2S, Ar, CO_2, and Rn. N_2, Ne, and Ar displayed no recognizable distribution patterns; an inverse relationship between CO_2 and O_2 was observed to reflect the biogeochemical environment of the samples. The concentration of dissolved He in frozen lakes from the Elloit Lake district was no greater than elsewhere (atmospheric equilibrium levels). Due to its high mobility, He, unlike is of limited valued as a tracer for U-mineralization. There is an apparent inverse relationship between H_2S and dissolved H_2 in ground water sampled from drill holes in Cu-deposits. H_2S appears to be of little value as an indicator of buried sulfide mineralization; its chemical and biological activity restrict its mobility in ground water and effectively obscure its origins. (LKH)

<42>
Dyck, W., S.H. Whitaker, and R.A. Campbell, Canada Geological Survey, Ottawa, Ontario, Canada

Well Water Uranium Reconnaissance, Southwestern Saskatchewan. Geological Survey of Canada Paper 76-1C, Report of Activities, Part C, (pp. 249-253). (1976)

Approximately 940 well and 60 spring water samples were collected from a 17,500 sq. km area of southwestern Saskatchewan near Cypress Hills. An average density of 1 sample per 13 sq km was sought. Samples were analyzed for U, Rn, F, O_2, Eh, pH, alkalinity, and conductivity. The following values were obtained: 0-240 ppb U, 0-4135 pCi/l Rn, 0-4.1 ppm F, 0.4-14 ppm O_2, -127 to 906 mv(H2el.) Eh, 4.86-8.02 pH, 8-1867 ppm $CaCO_3$ total alkalinity, and 110-3300 umhos/cm conductivity. Well depths ranged from 2 to 457 m. Formations involved were the Cypress Hills, Ravenscrag, Frenchman, Battle, Whitemud, Eastend, Bearpaw, and Judith River. It was concluded that none of the U or Rn values reflect ore-grade environments. Rn highs are more closely associated with the Cypress Hills Formation than are U highs. The short range of Rn in nature relative to U and the high relief in the western part of map area 72F suggest that the Cypress Hills Formation is the source of much of the U. Leaching of radioactive lignite in the Ravenscrag and older formations may contribute to the U values. The data also shows that for all formations deeper wells are lower in U and Rn. In general, the younger formations have higher Rn and lower U values than the older, and there is often a lateral shift of high-U sites downslope from high-Rn sites. This can be explained by the different mobilities and ranges of these elements in the near-surface environment. (LKH)

<43>
Eckelmann, W.R., and J.L. Kulp

Uranium-Lead Method of Age Determination: Part II: North American Localities. Bulletin of the Geological Society of America 68:1117-1140. (1957, September)

Many new isotopic age determinations by the uranium lead method have been made on most of the important North American localities from which primary uranium minerals have been reported. With the aid of other published isotopic U-Pb age measurements the writers attempted to interpret the most probable age for each locality and to assign a reasonable uncertainty to that age. The recognition of differential lead loss, the relation of alteration to mineral type, the importance of radon leakage for young samples, and the potential analytical errors make it timely to conduct such a re-evaluation. Among the well-established ages are: Spruce Pine district, North Carolina, 360 plus or minus 20 m.y.; Portland, Connecticut, 265 plus or minus 10 m.y.; Front Range, Colorado, 59 plus or minus 5 m.y.; Black Hills, South Dakota, 1620 plus or minus 20 m.y.; southeast Manitoba, 2650 plus or minus 100 m.y.; Lake Athabasca, Saskatchewan, 1900 plus or minus 50 m.y.; and the Wilber-force area, 1050 plus or minus 20 m.y. Other probable ages are Bedford, New York, 350 m.y.; Colorado Plateau, 60 m.y.; Cocur d'Alene, 1200 m.y.; and Great Bear Lake, Northwest Territories, 1500 m.y. Although there may have been several regional metamorphic events in the Appalachian Province in the Precambrian, the post-Cambrian effects appear at only two periods centering on 260 m.y. and 360 m.y. The Grenville metamorphism appears limited to a narrow time interval about 1050 m.y. ago. The Front Range and Colorado Plateau uranium mineralization may have been one event occurring about 60 m.y. ago. (Auth)

<44>

GEOCHEMISTRY

<44>
Felmlee, J.K., and R.A. Cadigan, USGS, Denver, CO

Determination of Uranium in Source Rocks Using Radium in Crystal Springs, Great Salt Lake Area, Utah. USGS Circular 753; Short Papers of the US Geological Survey Uranium-Thorium Symposium, 1977, J.A. Campbell (Ed.), (pp. 48-50), 75 pp. (1977)

The amount of uranium in source rock that would be required to produce the radium in the water of Crystal Springs, north of Brigham City, Utah, has been calculated in order to determine whether the source rock may have a potential for uranium concentrations of economic interest. Water samples were collected from 11 springs for radium, uranium, and major- and minor-element analysis. Precipitate samples were collected from 8 of the sites. Radium in the water has a positive correlation (0.82) with total dissolved solids and with most of the major and minor ions. The three springs having the lowest salinity also have the lowest radium content, less than 1 part per trillion (ppt), and one of the briny springs, Crystal Springs, has the most radium, 220-410 ppt. Some springs on faults within 20 km west of the Wasatch Range have moderately high salinity and radium content, 20-140 ppt. Others have moderately high salinity, but low radium concentrations (2-5 ppt). Such deviations reflect variations in unmeasured parameters, such as uranium content of the source rock, that affect the radium content of the water. The amount of radium in the water at Crystal Springs exceeds by several hundred times the amount of radium that would be in equilibrium with the amount of uranium in the water. The amount of enrichment, called the radium enrichment factor (REF), can be calculated by using the known equilibrium ratio for radium-226 and uranium-238 and by the measured radium and uranium per liter or minute at the spring. The REF at Crystal Springs is 430-880. The REF in the water depends on the difference in leach between radium and uranium when they are removed from the source and transferred to the spring. Differential leaching based on differences in response to such parameters as pressure, temperature, oxidation-reduction potential, ionic strength, and mineral phases, leads to disequilibrium within the rocks being leached. Differential leaching in favor of radium results in an excess of radium in the water and a corresponding depletion at the source. Continued differential leaching eventually leads to extreme disequilibrium in the leached part of the rock. The disequilibrium is actually between radium and its direct parent, Th-230, which is in relative equilibrium with uranium. Therefore, the uranium in the source rocks is calculated by assuming that disequilibrium in the rocks is extreme and that the only radium available for transport is the amount being produced each minute by Th-230. Crystal Springs contain at least 220 ppt [10(E-12) g/l)] radium and flows at 6,800 l/minute, yielding radium at 1.5 x 10(E+6) g/min. By assumption, this rate of yield is equal to the rate of radium production at the source. A production rate of 1.5 x 10(E+6) g/min radium is equivalent to the same decay rate of Th-230. The proportion of any amount of Th-230 [half life=8x10(E+4) years] decaying each minute is 1.7x10(E+11). Assuming secular equilibrium [1 g uranium balanced by 1.7x10(E+5)g Th-230), the amount of uranium required to maintain the present production of radium at Crystal Springs is at least 5.5x10(E+9) g, or 5,500 metric tons. The total volume of rock involved in the flow to Crystal Springs is on the order of 10 cubic kilometers. The mass of rock, assuming an average density of 2.8 g/cubic cm, is thus about 10(E+16) g. Whether the uranium is disseminated or concentrated in the source rock is uncertain. If the calculated 5.5x10(E+9) g uranium were disseminated in 10(E+16) g of rock, the content would be 0.55 ppm, but because porosity and permeability in the sedimentary-metamorphic terrane of the Wellsville Mountains are controlled mostly by joints and fractures, water flowing through these openings comes in contact with only a small percentage of the total rock. By assuming that the radium is derived from uranium in restricted zones adjacent to fractures and joints, considerably higher potential grades of uranium in the rock can be calculated. The grade would be 0.55 percent if the 5,500 metric tons of uranium were concentrated in 1 percent of a fracture system comprising 1 percent of the volume of rock assumed to be leached by the spring water. (JHT)

<45>
Filippov, M.S., and L.V. Komlev, V.G. Khlopin Radium Institute, Leningrad, USSR

Uranium and Thorium in the Granitoids of the Middle Dnepr Region. Geochemistry 5:535-549. (1959)

In the Middle Dnepr region there are three granitoid complexes different in age, composition, and geochemical characteristics. The evolution in the composition of the granitoids of the three complexes from the older to the younger consists of a decrease in the sodium, calcium, and magnesium content and increase in the content of potassium, silica, uranium, and thorium. The granitoids of the oldest complex, granodiorites and plagiogranites, contain the smallest amounts of uranium and thorium. The granites of the second complex have uranium contents approximating the clarke, and thorium contents higher than the clarke. The third complex of microcline alaskites is strongly enriched in the radioactive elements, especially thorium. The uranium content of these rocks is about twice the clarke and the thorium content is four times the clarke. According to the content of the most characteristic accessory minerals, the granitoids of the Middle Dnepr region are divisible into three types: a) the allanite-sphene type, b) the monazite-garnet type, and c) the thorite-molybdenite type. The allanite-sphene granites are the poorest in the radioactive elements. Uranium and thorium in these rocks are partially concentrated in the accessory minerals, with the rest apparently in the dispersed state, in essential minerals. The monazite-bearing granites are thorium-bearing; their high thorium content resulting from the accumulation of the accessory monazite. Zircon is also a chief concentrator of uranium and thorium in granites of this type. The thorite-bearing granites are still predominantly thorium-bearing rocks, but they also have a relatively high uranium content. Uranium and thorium in these granites are concentrated entirely in the accessory minerals, with thorite and zircon contributing 90 percent of the total content of these elements. (JHT)

<86>
Florence, T. L. (Ed.), Australian Atomic Energy Commission, Research Establishment, Lucas Heights, Sidney, Australia

Uranium and Thorium. Proceedings of a Symposium, Lucas Heights, Sidney, Australia, May 7-8, 1970. Australia Atomic Energy Commission, Sidney, 102 pp. (1970)

> Review papers are presented on the determination of uranium by radiometric, X-ray fluorescence, polarographic, spectrophotometric, fluorimetric, titrimetric, emission spectrographic, delayed neutron, gamma absorption, and gamma-excited X-ray techniques, and on the determination of thorium by radiometric and spectrophotometric methods. In addition, detailed analytical procedures are given for the determination of uranium and thorium in ores, rocks, and waters by most of these techniques. (Auth)

Each paper of the symposium has been abstracted and input separately.

<87>
Gabelman, J.W., AEC, Washington, DC

Uranium in the Appalachian Mobile Belt. RME-4107; 41 pp. (1968, March)

> The uranium occurrences in the Appalachian Mobile Belt comprise a belt of plutonic alkalic intrusives containing economic high-temperature uranium-thorium concentrations parallel to and southeast of the Grenville front; small concentrations associated with amphibole-magnetite-sulfide replacements in high-temperature iron zones; uraninite veins in gold-copper zones; low-temperature copper-uranium impregnations in late Paleozoic and Triassic sandstone superimposed on high-temperature iron and copper zones in hinterland basins; and small uranium impregnations in Paleozoic sandstone at the low-temperature ends of mineralization gradients along the foreland margin. These uranium occurrences in orogenic-related mineralization cycles, with metallotectonic gradients generally similar to those in the Cordillera where uranium is most abundant at the low-temperature ends, indicate that uranium of Paleozoic or Mesozoic cycles in the Appalachian belt also may be most prominent in the lowest temperature metallotectonic zone along the foreland margin. Although this zone is not now known to contain significant deposits, it may be a good exploration target. (Auth)(RBW)

<88>
Gavshin, V.M., V.A. Bobrov, A.O. Pyalling, and N.V. Reznikov, Academy of Sciences, Institute of Geology and Geophysics, Siberian Division, Novosibirsk, Siberia, USSR

The Two Types of Uranium Accumulation in Rocks by Sorption. Geochemistry International 5-6:682-690. (1974, June)

> The accumulation of uranium by sorption in phosphate-bearing rocks is accompanied by largely unexamined uraniferous products, where the main uranium sorbents are minerals of the layer silicate group. Sometimes uraniferous calcium phosphates and layered aluminosilicates occur in the same stratigraphic section, with the phosphates (carbonate-fluorapatite) occurring in fine-grained lagoon deposits, while the layered aluminosilicates (mainly hydromicas and chlorites) occur predominantly in the red bed and essentially psammite continental strata. The uraniferous carbonate-fluorapatite has uniformly distributed uranium together with thorium, rare earths, strontium, and barium, which probably take up the positions of calcium in the lattice. The apatite structure retains the uranium and its decay products firmly, so phosphate-bearing rocks have little inclination and little deviation from equilibrium between uranium and radium, and only low concentrations of uranium in water interacting with the phosphates. The uranium in uraniferous layer silicates is associated with some elements of variable valency and readily hydrolyzed elements (titanium, vanadium, zirconium, chromium, molybdenum, etc.). The uranium and decay products are much less firmly bound, and the emanation is rapid, with marked deviations from radioactive equilibrium. Oxidizing and reducing solutions quickly take up the uranium, and these silicates produce uraniferous solutions from which uranyl minerals can be deposited in the supergene zone or the so called primary uranium minerals under reducing conditions. (JMT)

<89>
Gavshin, V.M., and Yu.G. Lavrent'yev, Academy of Sciences, Institute of Geology and Geophysics, Siberian Division, Novosibirsk, Siberia, USSR

U-Ti Correlation in Cryptogranular Pelite. Geochemistry International 11(1):179-190. (1974)

> Uraniferous pelite from Devonian sandstones is a mechanical mixture of finely divided particles of hydromica, chlorite, albite, and quartz. Uranium atoms are randomly distributed in the pelitic material, and the titanium distribution is identical to that of the uranium. The uranium-titanium ratio in the pelitic material is higher than that in any known uranium-titanium mineral. The uranium accompanies the titanium throughout the pelite, and in places, gives rise to a dispersed uranium-titanium phase with a definite stoichiometric relation between the components. Metatitanic acid can absorb uranium from dilute solutions, consequently, the cause of the uranium concentration in the pelite was a dispersed metastable titanium hydroxide which formed in the aluminosilicate material. (JMT)

<50>

GEOCHEMISTRY

<50>
Gerling, E.K., and Ye.A. Shukolyukov, Academy of Sciences, Laboratory of Precambrian Geology, Leningrad, USSR

Accumulation of Ar-38 in Uranium Minerals. Geochemistry 7:750-764. (1959)

The argon-38 content of 17 uranium minerals, ranging in age from 2 x 10(E+8) to 2 x 10(E+9) years, was investigated. The content of U, Pb, rare earths, He, Xe, and Cl was also determined in the samples. Corretions for the argon-38 loss were made according to the data on the He and Xe losses. The calculated excessive quantity of argon-38 in minerals of the same age decreased with the increase of the Cl content. This may be explained by the reaction Cl-35 - Cl-36 - Ar-36. Corrections were made for argon-38 according to the quantities of radiogenic argon-36. There is a proportionality between the U content and the argon-38 content. Between the quantities of argon-38 and xenon of neutron fission, a dependence of the type Ar 38=aXe(sub n) [Xe(sub n) being xenon of neutron fission]. Samples were found which at a complete absence of Xe(sub n) contained noticable quantites of argon-38. The possibility of argon-38 formation by the spontaneous fission of U-238 and the neutron fission of U-235 was assumed. The argon-38 formation goes through the hypothetical radioactive isotope with T(sub ½)=(490 plus or minus 230) x 10(E+6) years. The yield of the latter by uranium fission must be 3 percent. (Auth)(JHT)

<51>
Goldhaber, M.B., and R.L. Reynolds, USGS, Washington, DC

Geochemical and Mineralogical Studies of a South Texas Roll Front Uranium Deposit. USGS OFR-77-821; 34 pp. (1977)

Core samples from a roll-front uranium deposit in south Texas were analyzed for iron sulfide content and mineralogy, organic carbon content and abundance of carbonate, iron, manganese, and titanium. Sulfide occurred almost exclusively as the iron disulfides pyrite and marcasite, in concentrations as high as 2 percent of the coarse (greater than 62 micrometers) fraction. Marcasite was particularly abundant relative to pyrite in the vicinity of the roll front. Because marcasite precipitation requires acidic pH's and the most likely mechanism for generating low pH is oxidation of preore sulfide, it is suggested that the marcasite formation was related to the roll-front development. Organic carbon analyses from various representative parts of the deposit are uniformly low (less than 0.1 percent C). Carbonate minerals, such as calcite, are abundant, but appear to have formed after the ore. The overall abundance of iron was not found to be systematically related to position with respect to the roll front, whereas manganese probably was concentrated near the redox interface. Titanium like iron did not show a systematic relationship to position about the roll, but it was systematically more abundant in the fine fraction (less than 62 micrometers) relative to the coarse fraction with distance downdip. This reflects a progressively more intense alteration of the precursor iron-titanium oxide minerals to fine-grained TiO2. (JHT)

<52>
Goldschmidt, V.M.

Uranium. Geochemistry, V.M. Goldschmidt. Oxford Press, London, (pp. 562-567), 730 pp. (1958)

The distribution of tetravalent uranium in the primary minerals of igneous rocks is determined by its radius (1.05 angstrom), which makes possible its capture by minerals containing calcium and trivalent rare earth ions, especially yttrium and the yttrium lanthanides. The similarity to the cerium lanthanides is not as close as in the case of the somewhat larger thorium minerals. Capture of uranium in primary calcium minerals of magmatic rocks probably occurs in apatites. Uranium also substitutes for calcium in fluorite, accounting for the radioactive varieties of fluorite such as those found at Wolsendorf in Bavaria. Uranium substituted for yttrium earth elements, especially in minerals of granite pegmatites, is found in a large number of minerals, especially niobates and titanoniobates. The entrance of tetravalent uranium into minerals of the thorite group suggests the possibility of an unknown compound USiO4 which could probably be made synthetically. The same compound is also a hypothetical end member of uraniferous minerals in the zircon family. Pleochroic halos in biotite or amphibole around minute zircon crystals, is due to the isomorphous entry of uranium or thorium into ZrSiO4. Primary uranium dioxide minerals relatively unchanged by secondary oxidation are seldom found. One of the processes concerned is intimately connected with the radioactive transformation of tetravalent uranium to divalent lead. Through this process, a number of oxygen atoms, equal in number to the uranium atoms transformed into lead, become available, and this surplus of oxygen is left to combine with UO2 and thus to form the equivalent amount of UO3. The migration and distribution of uranium during weathering and sedimentation is intimately connected with processes of oxidation and reduction. The oxidation of tetravalent uranium takes place easily by weathering, giving rise to transformation of the blackish UO2 and U3O8 minerals to the brightly colored yellow, orange, or green secondary minerals of the UO3 and the uranyl salts. Solutions of compounds of hexavalent uranium have a much higher degree of geochemical mobility. Their local circulation and redistribution give rise to a number of important uranium deposits. (JHT)

Some confusion exists in the literature as to the exact radius of the tetravalent uranium ion. Goldschmidt gives a figure of 1.05 angstroms, which is somewhat higher than the generally seen value of 0.97 angstroms. In actuality, the exact value for the radius for tetravalent uranium will vary according to the compound, co-ordination number, etc.

<53>
Goldschmidt, V.M.

Thorium. Geochemistry, V.M. Goldschmidt. Oxford Press, London, (pp. 427-431), 730 pp. (1954)

The geochemistry of tetravalent thorium is characterized essentially by its crystallochemical relationships with several elements having similar ionic radii. The ionic radius of tetravalent thorium is 1.10 angstroms. It is comparable in size with divalent calcium (1.06 Å), the trivalent rare earth elements, such as cerium (1.18 Å), and the trivalent yttrium group from gadolinium (1.11 Å) to lutecium (0.99 Å). Generally, the geochemistry of thorium in igneous rocks, like that of uranium, is closely connected with the later stages of the evolution of igneous magmas. The large radius of thorium makes it unfit to enter many of the important early crystallizates, such as the simple orthosilicates or metasilicates of magnesium and divalent iron. As a result, it is generally found concentrated in the light residual magmas from which are formed such rocks as syenites, trachytes, granites, and liparites. Some nepheline syenites and phonolites, in particular, may have remarkable concentrations of the element. Thorium, like uranium, is generally concentrated in some of the lightest residual magmas, the relatively low specific gravity of which causes these heaviest known atoms to accumulate in the upper levels of the silicate crust, concentrating there the bulk of the heavy radioactive matter; a fact of great importance in the physics of the earth. Similar considerations hold for the zonal distribution of the radioactive alkali metals, potassium and rubidium, and also for the radioactive rare earth metal samarium. Thus, a very great part of the total radioactive matter of the earth is presumably concentrated in a comparatively thin surface shell, a distribution which is even more enhanced by the fact that the free energy of oxidation of the primary radioactive elements per unit oxygen greatly exceeds that of iron or even silicon, so that only very minor proportions of these elements can be presumed to be constituents of the iron core of the earth. Thorium substitutes for calcium in apatite and fluorite, but crystallizing monazite seems to be the most suitable collector of thorium ions from igneous magmas and hydrothermal solutions. It is interesting to note that tetravalent uranium (1.05 Å), which is only slightly smaller than the thorium ion, is found in monazite to a very small extent, the concentration of uranium being about 100 times less than the concentration of thorium. The close crystallochemical and geochemical relationships between thorium and uranium are illustrated in a most characteristic way by the thorium minerals of the thorianite group, essentially isomorphous mixtures of dominant ThO_2 and subordinate UO_2, and the minerals of the thorite group, essentially isomorphous mixtures of $ThSiO_4$ and $USiO_4$, with $ThSiO_4$ greatly preponderating. The minerals of the thorianite group constitute a series from almost pure ThO_2 to a mixture containing up to about 40 per cent UO_2. The minerals of the thorite family had primarily a crystal structure which corresponded closely to that of zircon, but are now according to all cases so far studied, transformed to an amorphous metamict product, often modified by secondary hydration and also by secondary precipitation of iron oxide or hydroxide from percolating aqueous solutions. (JMT)

<54>
Goodfellow, W.D., and I.R. Jonasson, Canada Geological Survey, Ottawa, Ontario, Canada

Geochemical Distribution of Uranium, Tungsten, and Molybdenum in the Tombstone Mountains Batholith, Yukon. Geological Survey of Canada Paper 77-1B, Report of Activities Part B, (pp. 37-45), 350 pp. (1977)

The Tombstone Mountains Batholith was the subject of a detailed geochemical investigation in the summer of 1976, during a uranium-geology survey of the north central Yukon. The area is underlain by an alkaline batholith of Cretaceous age, intruding Cretaceous Keno Hill Quartzite, diorite, and gabbro, and Jurassic sedimentary rocks. The core of the batholith is an alkali syenite surrounded by monzonite, quartz monzonite, and diorite; the syenite makes up the bulk of the intrusion, and is composed of phenocrysts of orthoclase set in a medium-grained allotriomorphic groundmass of microperthitic orthoclase, andesine, aegirine-augite, amphibole, biotite, and minor quartz. Accessory minerals include sphene, zircon, apatite, and opaques. Stream sediment and water analyses for Au, Pb, Zn, Co, Ni, Ag, Mn, Fe, Ba, Mo, W, U, and F via AAS, colorimetry, fluorimetry, and specific ion electrode analysis are given. Whole rock analyses were also carried out. Most of the trace elements are mechanically rather than organically derived, and thus reflect well the chemistry of the batholith and immediately surrounding rocks. High U concentrations (14.4-24.7 ppm) associated with pseudoleucite tinguaite along the southern contact appear to result from U retention as a complex ion in a halogen and carbonate rich residual magma. The association of U with F is indicated by the presence of fluorite veins which intersect the tinguaite and U veins. The area of U mineralization is outlined by high U, Mo, W, Pb, and Zn in stream sediments and U, F, and Pb in stream waters. A second area near the center of the batholith is also outlined by similar associations, although no tinguaite has been mapped. However, in view of the geochemical data, it must be considered an area of high U and W potential. (LEH)

GEOCHEMISTRY

<55>
Gosnold, W.D., Jr., Southern Methodist
University, Dallas, TX

A Model for Uranium and Thorium Assimilation by Intrusive Magmas and Crystallizing Plutons through Interaction with Crustal Fluids. Ph.D. Thesis; 131 pp. (1977)

Evidence for interaction between intrusives and meteoric ground water, in addition to information on the occurrence and distribution of uranium and thorium in the continental crust, suggests that intrusive magmas may mobilize and assimilate uranium and thorium through interaction with crustal fluids. Investigations of the distribution of uranium, thorium, and potassium within and around eight epizonal plutons show mobilization and redistribution of uranium and thorium in the contact aureoles of plutons which have interacted with meteoric ground water. In these plutons uranium is shown by induced fission track radiography to be associated with both primary and secondary hydrous minerals and with secondary opaque minerals. Plutons which have not interacted with meteoric ground water show little association between uranium and hydrous or opaque minerals. Studies of epizonal, mesozonal, and catazonal plutons in the Idaho batholith show that the highly radioactive epizonal plutons contain much uranium in hydrous and secondary minerals, whereas the low radioactivity mesozonal and catazonal plutons do not. The apparent exponential vertical distribution of radiogenic heat production in plutonic rocks can be explained by an assimilation model in which the degree of assimilation increases toward the surface as a result of increasing accessibility of crustal fluids, particularly meteoric ground water. (Auth)

<56>
Granger, H.C., and C.G. Warren, USGS, Denver, CO;
USGS, Fort Collins, CO

Unstable Sulfur Compounds and the Origin of Roll-Type Uranium Deposits. Economic Geology 64(2):160-171. (1969)

Roll-type uranium deposits are formed by a supergene process that depends on limited oxidation of early formed pyrite in the host rock. Among the initial products of oxidation is a series of unstable soluble sulfur species, principally sulfite, which slowly decompose and ultimately form sulfate and sulfides. Because sulfate is kinetically inert to low-temperature nonbiologic oxidation-reduction reactions, and because the unstable sulfur species and hydrogen sulfide are strong and active reducing agents, the net result of limited oxidation is to produce a strongly reducing environment. Either some of the intermediate sulfur products or hydrogen sulfide may recombine with ferrous iron under these conditions to form the iron sulfide minerals associated with the ores. Laboratory experiments and chemical theory suggest that the entire sequence of reactions can be carried out in a biologically sterile environment and that the sulfur isotopic composition of the reconstituted pyrite might be indistinguishable from pyrite formed by biogenic processes. These unstable intermediate sulfur species may also be involved in the formation of other supergene-enriched sulfide ores as well as in the transportation and deposition of elements such as barium and selenium. (Auth)

Cited as a reference in NURE Contractor Reports.

<57>
Bulakh, A.G., A.A. Nazalov, A.A. Saturin, and
A.V. Bakhtiarov, Leningrad State University,
Leningrad, USSR

Distribution of Uranium and Thorium in the Alkalic Rocks of the Turiy Peninsula (Murmansk Region). Geochemistry International 9-10:1063-1065. (1974, August)

The alkalic massifs of the Turiy Peninsula are typical representatives of the Caledonian alkalic ultramafic formation. They are composed of two series of rocks: (1) an alkalic ultramafic series, including olivinites, peridotites and alkalic pyroxenites, and (2) an alkalic series, including nepheline pyroxenites, melteigites, ijolites, melilite-bearing rocks, rocks of the "mineralized complex" (forsterite-magnetite) and carbonatites. Thorium and uranium contents of the rocks in the central massif were determined by gamma-ray spectroscopy. In the series of magmatic rocks, thorium and uranium concentrations increase from pyroxenites (Th=11.8 ppm, U=2.1 ppm) to ijolites (Th=15.1 ppm, U=8.6 ppm). The main mass of thorium in alkalic rocks is concentrated by sorption in fractures, defects, and altered areas of crystals. A fraction of the uranium is also concentrated in this way in the rocks of the central massif. In addition, uranium and thorium enter isomorphously into the accessory minerals schorlomite, perovskite, sphene, gotzenite, and others. The relatively high uranium and thorium contents are characteristic of ijolites rich in garnet. (JRT)

GEOCHEMISTRY

<58>
Haughton, D.R., Saskatchewan Research Council,
Geology Division, Saskatchewan, Canada

A Multiple Media Geochemical Survey of a Boulder Train Associated With the Duddridge Lake Uranium Deposit, Saskatchewan. Saskatchewan Research Council Report 17; 55 pp. (1976)

> A geochemical survey was carried out in the summer of 1975 at the Duddridge Lake U deposit in the Wollaston Lake Fold Belt of northern Saskatchewan. 85 outcrop samples, 260 float samples, 992 overburden A0 samples, 898 overburden B1 samples, 488 muskeg A0 samples, and 796 lake sediment samples were collected and analyzed for Cu, Zn, Ni, Pb, Mo, U, Co, and Fe. Mn was measured in lake sediments. Outcrops are rare, but a gamma ray survey of K 40, U 238 (Bi 214), and Th 232 (Tl 208) emissions revealed a northeast-southwest trending fold pattern in the bedrock which was supported by drilling evidence. Generalized bedrock geology consists of the following stratigraphic sequence from east to west: biotite gneiss (magnetite), meta-arkose with an intruded pegmatite and pegmatitic granite body, and meta-arkose grading into biotite-feldspar gneiss. Geochemical analysis successfully delineated a U-mineralized boulder train associated with a carbonaceous feldspathic quartzite (meta-arkose) horizon of Hudsonian age, possibly of roll-front or diagenetic origin; overburden A0 and B1 were equally suitable for defining the mineralization. Cu and U positively correlated in all unconsolidated materials; no positive correlations were obtained between U and other elements in outcrop samples. U in finer grain size fractions of overburden B1 and C samples has higher metal values than those from coarser grain sizes. (LKH)

Seventeen maps are included in this report. Statistical analyses of element distributions in various sample groups and maps of their distribution are provided.

<59>
Henderson, P., University of London, Chelsea
College, Department of Geology, London, England

Geochemical Indicator of the Efficiency of Fractionation of the Skaergaard Intrusion, East Greenland. Mineralogical Magazine 40:285-291. (1975, September)

> When magmatic fractionation involves the settling and removal of crystals from the body of magma, the efficiency of the fractionation process may be defined as the degree of separation of the solid from the liquid phase. An expression is given that relates efficiency to the amount of mesostasis, or crystallized trapped liquid, in an igneous cumulate. The uranium content of samples from a 309 meter long drill core of part of the lower and hidden zones of the Skaergaard intrusion is used as a quantitative indicator of the amounts of mesostasis in the cumulates. There are marked changes in the amount of mesostasis over the length of the core, and the average efficiency of fractionation was 85 percent. (Auth)

<60>
Henderson, P., A. Mackinnon, and N.H. Gale,
Chelsea College of Science and Technology,
Department of Geology, Chelsea, England; Oxford
University, Department of Geology and Mineralogy,
Oxford, England

The Distribution of Uranium in Some Basic Igneous Cumulates and its Petrological Significance. Geochimica et Cosmochimica Acta 35:917-925. (1971)

> The distribution of uranium in the minerals and rocks of the Skaergaard, Rhum, and Bushveld layer igneous intrusions was investigated by the delayed neutron analytical technique. The uranium concentration in the minerals depended in part on the nature of the cumulate from which they were separated. Of those minerals from accumulates, pyroxene contained the most uranium and olivine the least. The uranium content of a basic igneous cumulate is shown to be useful as an indicator of the relative amount of mesostasis in the rock, provided uranium-bearing cumulus minerals such as apatite are absent. The amount of mesostasis sometimes changed rapidly from one layer to another. (Auth)(JHT)

<61>
Howard, J.H., III, University of Georgia,
Department of Geology, Athens, GA

Geochemistry of Selenium: Formation of Ferroselite and Selenium Behavior in the Vicinity of Oxidizing Sulfide and Uranium Deposits. Geochimica et Cosmochimica Acta 41:1665-1678. (1977)

> The geochemistry of selenium is largely controlled by that of iron, with which selenium is closely affiliated in both oxidizing and reducing environments. In aerated waters the Se(IV) oxyanions, HSeO4- and SeO3-2, are strongly adsorbed by hydrated surfaces of ferric oxides over the pH range 2-8; above pH 8 adsorption decreases to complete desorption at pH 11. This adsorption immobilizes Se(IV) in neutral-to-acid waters and increases the range of oxidation potential over which Se(IV) is stable. During experimental aeration of aqueous Fe-S-Se systems, the stability field of Se(IV) is attained, and elemental Se is slowly oxidized to this higher valence; oxidation potentials of the Se(VI) stability field were never reached, however, even by continued aeration of an alkaline system. Under reducing conditions, elemental Se either is incorporated within pyrite or forms the mineral ferroselite (FeSe2). A stability field for ferroselite, constructed for a Gibbs free-energy value of -23.2 kcal/mole, is in accord both with its geologic occurrence and behavior and with conditions under which ferroselite has been synthesized. Traces on a diagram of Eh-pH variation show the behavior of selenium during oxidation of associated iron-sulfide minerals. Such considerations also demonstrate the manner in which selenium migrates, is deposited, and is increasingly concentrated in roll-type sandstone uranium deposits, as well as the relative positions of the several forms of selenium within the deposit. (Auth)

<62>

GEOCHEMISTRY

<62>
Ingerson, E., S. Valastro, Jr., University of Texas, Austin, TX

Geochemistry of South Texas Uranium Deposits. AAPG Bulletin 63(3):472-473. (1979, March)

During the past several years attempts have been made to unravel the geochemistry of south Texas uranium deposits by analyzing core samples obtained from several localities within the mineralized province and from various prospective mines. The core samples were taken from three different sections of the geochemical cell--the oxidation, ore, and protore zones. All samples selected for analysis belong to the same stratigraphic interval as the ore zone. Measurements of pH and Eh taken in the field range as follows: oxidation zone, pH 7.2 to 5.6 and Eh -60 mv to +50 mv; ore zone pH 4.1 to 3.6 and Eh +210 mv to +155 mv; protore zone, Ph 2.6 to 4.2 and Eh +210 mv to +180 mv. Analyses of total organic carbon, pyritic sulfur, and uranium have also been conducted. The total organic carbon content is generally low, but increases toward the protore to approximately 0.273 percent. Although the occurrence of pyritic sulfur is low in the oxidation zone, it increases from 0.015 to 0.696 percent in the protore. Evidence also indicates an increase with proximity to the roll front. Uranium is most prevalent in the ore zone, with a maximum value of approximately 290 ppm for the samples studied. In the protore, it ranges from 37 to 44 ppm. Adsorbed hydrocarbon analysis shows little evidence of petroleum migration from the downdip section of the deposits thus far analyzed. (Auth)

<63>
Irwin, G.A., and C.B. Hutchinson, USGS, Tallahassee, FL

Reconnaissance Water Sampling for Radium 226 in Central and Northern Florida, December 1974 - March 1976. USGS/WRD/WRI-77/001; 16 pp. (1976, October)

One hundred fifteen water samples were collected from wells in the shallow sand aquifer and in the upper and lower parts of the artesian aquifer of northern and central Florida, and from surface waters of the Peace River drainage basin. Samples were analyzed by the radon emanation method. Waters from Polk, Hardee, Hillsborough, Manatee, and De Soto Counties, taken as a group, contained from 0.05-90 pCi/l Ra 226; activity greater than 3 pCi/l was found in all aquifers in wells from 7 to 850 m deep. All surface samples contained less than 3 pCi/l, with the exception of one from a slime pit. Of 77 sites sampled in these counties, 16 did not meet U.S. Public Health Service drinking water standards. The shallow sand aquifer had both the highest and lowest Ra values. Acidified samples from Hamilton, Suwannee, and Columbia Counties displayed a range of 0.9-13 pCi/l Ra. There is evidence that acidification of samples before analysis may cause higher Ra values in some cases. Surface water samples from the Peach River basin had 0.10-7.6 pCi/l Ra, with a mean of 0.94 pCi/l and a standard deviation of 0.91 pCi/l; the maximum value was in Little Charlie Creek, the only stream exceeding 3 pCi/l. Since this reconnaissance was limited mainly to areas of active phosphate mining, it is not known if similar Ra values occur in portions of the state without phosphate deposits. (LKH)

<64>
Isaeva, A.A., V.I. Golovanov, and O.B. Presnyakova

Spectrophotometric Determination of Uranium in Sea Water and Various Types of Synthetic Sorbents. Soviet Radiochemistry 19(1):76-78. (1977, September)

A method developed for the determination of uranium in sea water and synthetic sorbents and used in the study of the possibility of concentrating trace elements from sea water is discussed. The method is based on the extraction with hydrochloric acid, and the formation of a complex of the isolated uranium with arsenazo III. The accuracy of the proposed method of analysis is 10.6 percent rel. (Auth)(JMT)

<65>
James, G.W., Kansas Geological Survey, Lawrence, KS

Parts-per-Million Determinations of Uranium and Thorium in Geologic Samples by X-ray Spectrometry. Analytical Chemistry 49(7):967-969. (1977, June)

Low levels (0 to 100 ppm) of uranium and thorium in geologic samples may be determined rapidly and accurately by wavelength-dispersive x-ray emission spectrometry. Three sigma detection limits of 1.2 ppm U and 1.5 ppm Th can be achieved with a total counting time of 5 minutes on a powdered 10-g sample. The estimated standard errors of the analytical calibration curves are 0.7 ppm U and 1.2 ppm Th. The method is applicable to a broad variety of sedimentary and igneous rock types; matrix effects are sufficiently corrected by a peak -to-background ratio method of data reduction. The mean difference between values obtained fluorimetrically and by x-ray spectrometry for 36 exploration samples containing 1.0 to 20 ppm U was 0.8 ppm. (Auth)

<66>
Johnson, C., Michigan Technological University, Department of Geology and Geological Engineering, Houghton, MI

Uranium and Thorium Content in Igneous Rocks. GJBX-98(76); Uranium and Thorium Occurrences in Precambrian Rocks, Upper Peninsula of Michigan and Northern Wisconsin, with Thoughts on Other Possible Settings, J. Kalliskoski, (pp. 136-142), 294 pp. (1976, June)

Twenty-six granite gneiss samples were collected from the Watersmeet-Marenisco area, and analyzed for uranium and thorium by means of the Neutron Activation Analyses. Because the limit of detection for uranium and for thorium by the Neutron Activation Analysis method is approximately 2 ppm, fluorometric analyses for uranium were also performed on whole rock samples. The uranium contents of the rocks sampled ranged from 31 ppm to 1 ppm. The thorium contents ranged from 70 to less than 2 ppm. High Th/U ratios in many of the samples indicate a possible uranium loss. (JMT)

GEOCHEMISTRY

<67>
Josa, J.M., J.L. Merino, and T.A. Villoria, Direccion de Plantas Piloto e Industriales, Junta de Energia Nuclear, Madrid, Spain

Spanish Radioactive Lignites; Nature and Solubility of the Uranium. Processing of Low-Grade Uranium Ores, Proceedings of a Panel, Vienna, June 27 - July 1, 1966. International Atomic Energy Agency, Vienna, (pp. 157-171), 247 pp. (1967)

Seventy samples of radioactive lignites from various places in Spain are discussed. The uranium contents of the samples ranged between 20 and 1200 ppm. Experiments on uranium extraction both by direct treatment and after roasting to eliminate organic matter and bring about concentrations were carried out. The acid method was considered for leaching the uranium using agitation and static bed techniques. Investigations were also carried out on the effect of the variables represented by grain size, amount of acid, temperature time and oxidants, in addition to those involved in the roasting process. (JMT)

<68>
Joshi, L.U., and A.K. Ganguly, Bhabha Atomic Research Centre, Division of Radiological Protection, Bombay - 400085, India

Anomalous Behavior of Uranium Isotopes in Coastal Marine Environment of the West Coast of India. Geochimica et Cosmochimica Acta 40(12):1491-1496. (1976)

An anomaly between U 238 and U 234 activities was observed in the top layers of the coastal sediments along the western region of the Indian sub-continent. Sediment samples from Bombay to Kottilppad were leached with saturated ammonium carbonate solution to extract uranium isotopes from the surface layers of the sediment particles without attacking the mineral cores. The U 234/U 238 activity ratios in these leachates are in the range of 1.12-1.14 while U 235/U 238 activity ratio is 0.046 which is the same as for other natural uranium. The surface organic matter from the sediment particles was removed by treatment with hydrogen peroxide in presence of 0.05 N hydrochloric acid. U 234/U 238 and U 235/U 238 activity ratios in the extract and the residues were determined. It is observed that disequilibrium between U 238 and U 234 exists only on the surface of sediment particles. U 234/U 238 on the surface of the sediment particles is the same as in the ambient water and as the surface organic matter is removed from the particle surface, the cores show equilibrium activities. (Auth)(JMT)

<69>
Kalil, F.K., University of California, Los Angeles, CA

The Distribution and Geochemistry of Uranium in Recent and Pleistocene Marine Sediments. Ph.D. Thesis; 267 pp. (1976)

Uranium in Recent marine shelf sediments is generally thought to originate from two sources. A small part of the uranium is thought to come from the land, while the majority of the uranium is believed to be extracted from sea water by the sediments. High concentrations of organic matter and reducing conditions within the sediment appear necessary for uranium incorporation into the sediments. The mode of uranium incorporation in Recent marine sediment has been examined by this study. The areal distribution of uranium both in surface and buried sediments was surveyed. Sediment samples, representing a wide range of oxidizing and reducing conditions and containing various amounts of organic carbon were analyzed. Organic isolates from the sediment were also examined. Sediments were collected from the Southern California Borderland, the Gulf of California, and the North Atlantic Ocean. Uranium was measured by standard alpha counting techniques and by counting delayed neutrons. An automated system was built at the UCLA nuclear reactor for counting delayed neutrons. This system accomodates 24 samples an hour with minimum radiation exposure to the operator. Sediment squeezers were designed and built to extract the pore waters from the sediment for chemical analysis. This enabled the measurement of the oxidation-reduction state of the sediments and the nature of diagenetic reactions. Results indicate that reducing conditions in the sediment are not important for extracting uranium from sea water. In the southern California shelf sediments, organic matter contains about one-third of the total sediment uranium. Much of this organic matter is probably land derived as is most of the uranium. The uranium distribution with depth depends on climatic fluctuations with maximum uranium deposition occurring during glacial periods. The detailed uranium distribution profile provided in this study may prove to be a useful tool for time stratigraphic correlations. (Auth)(JMT)

<70>
Kimberley, M.M., University of Toronto, Erindale College, Department of Geology, Mississauga, Ontario, Canada

High-Temperature Uranium Geochemistry. Uranium Deposits, Their Mineralogy and Origin, Short Course Handbook, Volume 3, M.M. Kimberley (Ed.). University of Toronto Press, Toronto, Canada, Ch. 3, (pp. 101-104), 521 pp. (1978, October)

High-temperature uranium geochemistry is not well known at present. The key question in the field is the effect of temperature on uranium solubility. Evidence that certain uranium ores have precipitated from high-temperature solutions largely consists of high homogenization temperatures for fluid inclusions in certain deposits. Pitchblende (fine-grained, thorium poor uraninite) is the dominant ore mineral in uranium deposits interpreted to have formed from hydrothermal solutions. Hematite, quartz, calcite, graphite, and chlorite are the most common gangue and wall rock minerals in the vein type deposits. The origin of pitchblende-vein deposits is currently highly controversial. (JMT)

GEOCHEMISTRY

<71>
Kimberly, M.M. (Ed.), University of Toronto, Erindale College, Earth and Planetary Sciences, Mississauga, Ontario, Canada

Uranium Deposits, Their Mineralogy and Origin. Short Course Handbook, Volume 3; 521 pp. (1978, October)

"Uranium Deposits, Their Mineralogy and Origin", contains 21 chapters concerning the field of uranium geology, geochemistry, mineralogy, as well as papers concerning the origin of uranium deposits throughout the world. All 21 of these chapters have been abstracted for the NURE Bibligraphic Data Base separately. (JHT)

<72>
Kleeman, J.D., D.H. Green, and J.P. Lovering, Australian National Universit~~y, Departm~~ent of Geophysics and Geochemistry, Canberra, Australia

Uranium Distribution in Ultramafic Inclusions from Victorian Basalts. Earth and Planetary Science Letters 5:449-458. (1969)

The uranium distribution in all phases of nine lherzolite inclusions from the Newer Volcanics of western Victoria has been determined using fission tracks. Primary clinopyroxene has a mean content of 0.30 ppm U in five of the inclusions, and two contain primary apatite with 35 ppm U. Secondary clinopyroxene and apatite crystallizing in equilibrium with glass formed from partial melting of the lherzolites have a much lower abundance. Partition coefficients calculated from the uranium contents in these secondary phases and the glass indicate that a liquid in equilibrium with the primary assemblage would have had to contain 25 to 75 ppm U. Since these abundances are at least ten times those of normal basalts, these inclusions could not have formed as accumulates from a basaltic magma, neither are they the residue from a previous episode of complete magma extraction. However other inclusions containing clinopyroxene with a low uranium abundance could be accumulates or residual. A model for the uranium distribution in the upper mantle is based on the uranium abundances in the high U primary assemblage. It is consistent with estimates of the upper mantle uranium content, and the uranium contents of basalt magma series calculated from it are consistent with the reported abundances. The petrology and geochemistry of inclusions illustrate a mechanism for limited wall rock reaction, and suggest that potassium may be moved without uranium. (Auth)

<73>
Koch, G.S., Jr., R.F. Link, and S.W. Hazen, Jr., Bureau of Mines, Washington, DC

Statistical Interpretation of Sample Assay Data from the Mi Vida Uranium Mine, Big Indian District, San Juan County, Utah. Bureau of Mines Report of Investigations 6550; 40 pp. (1964)

The Mi Vida uranium mine is located in the Big Indian District in northern San Juan County, Utah. The ore deposit is composed of uranium and vanadium minerals in the sedimentary beds of the Triassic Chinle Formation. Statistical analysis of assays of samples taken from the ore body affords an estimate of the grade of the ore body and provides a prediction about the direction of best mineralization beyond th e sampled area. The basic data analyzed are assay results for uranium (U308), vanadium (V205), and lime (CaO) from 225 channel samples cut at 79 sample points. By using appropriate statistical methods, particularly regression analysis, the grade of ore may be estimated more precisely than by conventional means, and the favorable direction to extend the mine may be predicted. Frequency distributions of assay residuals for uranium, vanadium, and lime are compared to frequency distributions of assays without regard to trend. Correlations among these variables are obtained and interpreted. (Auth) (JHT)

<74>
Kochenov, A.V., and V.V. Zinev'yev

Some Features of the Accumulation of Uranium in Peat Bogs. Geochemistry 2(1):65-70. (1965)

Supergene accumulations of uranium may form in a humid climate in the absence of high uranium concentrations in the surrounding bedrock. The content of uranium in circulating waters may be only slightly higher than the background content. The accumulation of uranium in peat requires a combination of several factors. Rejuvenation of relief as a result of neotectonic movements is essential because it introduces considerable masses of uranium dispersed in the bedrock into the supergene cycle and the uranium concentration in surface waters is increased. The geomorphic features of the provenance area and the hydrodynamics of ground water within the peat deposit are important factors in the localization of uranium concentrations. Only in a limited number of cases could all the favorable factors combine to cause supergene accumulations of uranium in peat. The fixation of uranium in peat is a result of combined action of sorption and reduction of uranium. The superposition of the oxidation-reduction reactions on the sorption processes results in the most stable association between uranium and organic matter and is the typical mechanism of accumulation of uranium in modern sediments. (JHT)

GEOCHEMISTRY

<75>
Koval'skiy, V.V., and I.Ye Vorotnitskaya, V.I. Vernadskii Institute of Geochemistry and Analytical Chemistry, Moscow, USSR

Biogenic Migration of Uranium in Lake Issyk-Kul'. Geochemistry 2(3):544-551. (1965)

The role of living organisms in the migration of uranium in Lake Issyk-Kul' was studied. The lake has no outlets, the weakly alkaline waters are of the sodium- and magnesium-rich chloride and sulfate types, and the waters have a relatively high uranium content. Physicochemical data suggest that uranium occurs in the waters in the form of uranyl-carbonate complexes. Some of the uranium is precipitated from the lake in the form of relatively insoluble calcium and magnesium carbonates as evaporation causes saturation. Within the lake muds, the content of uranium can be directly correlated with the content of organic matter. It was found that the algal genus CHARA were the most efficient concentrators of uranium, with dried CHARA containing up to 1000 times more uranium than the lake water. There was also a direct correlation between the content of uranium in the algae and in the underlying mud. Because algae absorb the uranium from the water and not from the mud and because uranium was shown not to be leached from dead algal remains, the uranium in the bottom muds was contained in the algal debris. The content of uranium in benthonic and planktonic organisms was found to be lower by a factor of ten than in algae, and in fish it was still lower, presumably because of partial uranium excretion. (JBT)

<76>
Krylov, A.Y., V.G. Khlopin Radium Institute, Leningrad, USSR

Radioactivity of Various Rock Complexes of the Terskei Ala-Tau Mountains. Geochemistry 3:240-247. (1958)

Several thousand rock specimens of various complexes in the Tyan-Shan area were analyzed for uranium, thorium, and potassium. It was found that during the formation of the granitic batholiths, the radioelements were carried together with silicon and the alkalis. At the same time, calcium and magnesium were carried out in considerable quantities, along with iron, manganese, and titanium, although to a somewhat lesser degree. This tendency increased in second phase granites which represented the further development of the magmatic process. (JBT)

<77>
Lambert, I.B., and K.S. Heier, Australian National University, Department of Geophysics and Geochemistry, Canberra, Australia

The Vertical Distribution of Uranium, Thorium, and Potassium in the Continental Crust. Geochimica et Cosmochimica Acta 31:377-390. (1967)

Uranium, thorium, and potassium contents from approximately 400 rocks from the Australian shield were determined by gamma-ray spectrometry. Felsic amphibolite facies gneisses have uranium and thorium contents indistinguishable from those of hornblende granulite subfacies rocks and intrusive shield granites. Pyroxene granulite subfacies rocks of similar bulk chemical composition have significantly lower abundances of uranium and thorium. In the mafic rocks studies, the uranium and thorium contents and the Th/K and U/K ratios show no variation with metamorphic grade. The lower uranium and thorium concentrations in the felsic pyroxene granulite subfacies rocks is related to the processes of metamorphism, including partial melting and upward movement of granitic material and vapor. The overall average contents of Th and K in the surface rocks of the West Australian basement shield appear to be similar to the overall average contents of these elements in the Paleozoic rocks outcropping in East Australia. However, the shield seems to be depleted in uranium relative to the younger orogenic region. It has been calculated that the surface heat production of the shield is only about 25 percent less than that of the Paleozoic rocks. This is compared with the difference of about 60 percent in the average heat flows measured in the two regions. (JBT)

<78>
Lambert, I.B., and K.S. Heier, Australian National University, Department of Geophysics and Geochemistry, Canberra, Australia

Estimates of the Crustal Abundances of Thorium, Uranium, and Potassium. Chemical Geology 3:233-238. (1968)

Radioactive element abundances in two crustal sections are estimated from surface heat flow, radioactive element abundances at the surface and in medium to high pressure granulite facies rocks, crustal thicknesses and assumptions of heat flow from the mantle. The abundances are 4.5 ppm Th, 0.7 (or 1.1) ppm U, and 1.5 percent K in the Archaean shield of southwest Australia. In the Paleozoic crust of east Australia, radioelement abundances were 7 ppm for Th, 1.3 (or 1.7) ppm for U, and 1.7 percent for K. The radioactivity in the shield is strongly concentrated near the surface and the thickness of the surface layer is estimated at 4.5 km. (Auth) (JBT)

<79>
Lambertson, W.A., and M.H. Mueller, Argonne National Laboratory, Metallurgy Division, Lemont, IL

Uranium Oxide Phase Equilibrium Systems: III, UO2-ZrO2. Journal of the American Ceramic Society 36(11):365-368. (1953, November)

The UO2-ZrO2 phase equilibrium system was investigated and found to contain no new compounds. The system did, however, contain extensive solid solution. The UO2 solid solution was cubic and extended up to 52 mole percent ZrO2. Its lattice parameter varied from 5.46 to 5.32 atomic units with an increasing percentage of ZrO2. The zirconia solid solution was examined by quenching techniques and found to be tetragonal and extended from 53 to 100 percent ZrO2. There were some indications that ZrO2 transformed to a polymorphic form other than monoclinic or tetragonal at approximately 1900 degrees C. (Auth) (JBT)

GEOCHEMISTRY

<80>
Langford, F.F., University of Saskatchewan, Department of Geological Sciences, Saskatoon, Saskatchewan, Canada

Mobility and Concentration of Uranium in Arid Surficial Environments. Uranium Deposits, Their Mineralogy and Origin, Short Course Handbook, Volume 3, M.M. Kimberley, (Ed.). University of Toronto Press, Toronto, Canada, Ch. 15, (pp. 383-394), 521 pp. (1978, October)

The association of uranium deposits with terrestrial redbeds has focused attention on the arid environment as one which may be particularly favorable. At present, the most important uranium deposits associated with arid environment is at Yeelirrie in Australia. This ore deposit consists of carnotite in fractures and as cavity coatings in valley calcrete, which is a body of limestone and dolomite that formed within the alluvium and soil along the axis of a valley. Yeelirrie is typical of most uranium occurrences in calcrete, of which there are locally a number of small deposits. The only uranium mineral in the deposits is carnotite. The calcrete and associated calcareous alluvium are the only host of significant uranium mineralization. During the rainy season, the calcrete area is subjected to fairly heavy showers, and although evaporation is high, sufficient waste descends below the zone where evaporation takes place. In these areas, there is complete flushing of the soils and, in the absence of carbonate and clays, uranium and vanadium are carried through the alluvium to the calcrete zone. The precipitation of carnotite can be caused by several chemical environments. (JMT)

<81>
Langmuir, D., The Pennsylvania State University, Department of Geosciences, University Park, PA

Uranium Solution-Mineral Equilibria at Low Temperatures with Applications to Sedimentary Ore Deposits. Uranium Deposits, Their Mineralogy and Origin, Short Course Handbook, Volume 3, M.M. Kimberely (Ed.). University of Toronto Press, Toronto, Canada, Ch. 1, (pp. 17-55), 521 pp. (1978, October)

Thermodynamic data was collected, critically evaluated, and estimated when necessary for 42 dissolved uranium species and 30 uranium solid phases. The data indicate that the uranium in natural waters is usually complexed. Near 25 degrees C in ground waters with typical concentrations of carbonate, chloride, fluoride, phosphate, and sulfate, under anoxic conditions, uranous (U+4) fluoride complexes predominate below pH 3-4 and uranous hydroxy complexes at higher pH's. However, because of the extreme insolubility of uraninite and coffinite [U less than 10(E-13)M or 10(E-4) ppb] at pH 4-5, concentrations of the uranous hydroxy complexes are generally below detection except in relatively alkaline waters. In oxidized natural waters with typical amounts of the same ligands: below pH 5, uranyl (UO2+2) fluoride complexes and UO2+2 predominate; from about pH 4-7.5, UO2(HPO4)2-2 is the important species; while at higher pH's, uranyl di- and tricarbonate complexes predominate. Uraninite and coffinite are extremely insoluble at normal ground water pH's (4-8) making the uranium practically immobile in low Eh environments. At intermediate Eh's, however, oxidation and leaching of uraninite and coffinite are greatly enhanced when phosphate and carbonate are present to form the highly stable uranyl complexes. The uranyl minerals carnotite, tyuyamunite, autunite, potassium autunite, and uranophane are least soluble at pH's within the range 5-8.5. Solubilites of carnotite and tyuyamunite are sufficiently low that in this pH range less than 1-2 ppb uranium could be present in a ground water saturated with them. The autunites and uranophane are typically at least one hundred times more soluble than carnotite and tyuyamunite, and rarely precipitate from ground water except near uranium-rich source rocks such as granites, low in V but high in P or silica. The pH range of minimum solubility of the uranyl minerals is also the pH range of maximal uranyl sorption on most important natural colloidal materials, including organic matter, Fe(III) oxyhydroxides, Mn and Ti oxyhydroxides, zeolites, and clays. Solubility and sorption data show uranyl to be least mobile in the pH range 5-8.5. Mineral solubilities limit only maximal uranyl concentrations whereas sorption limits uranyl concentrations at all levels below saturation with the least soluble uranyl mineral in a given water. In contrast to solubility control, the highest percentage of the total uranium in a sediment-water system is sorbed on the sediment at the lowest dissolved U levels. (JMT)

GEOCHEMISTRY

<92>
Langmuir, D., and K. Applin, The Pennsylvania State University, Department of Geosciences, University Park, PA

Refinement of Thermodynamic Properties of Uranium Minerals and Dissolved Species, with Application to the Chemistry of Ground Waters in Sandstone-Type Uranium Deposits. USGS Circular 753; Short Papers of the US Geological Survey Uranium-Thorium Symposium, 1977, J.A. Campbell (Ed.), (pp. 57-60), 75 pp. (1977)

Thermodynamic data was collected and critically evaluated for 25 minerals and 42 dissolved species of uranium. The data show that complexing of uranyl (UO2+2) and uranous (U+4) ions is the rule in natural waters, and is more important than generally realized. The existence and stability of these complexes indicates that the mobility of uranium in water may be enhanced under a wide variety of conditions. The study also shows that the solubility of uraninite (and coffinite) is about 8 to 10 orders of magnitude less than was previously indicated. This suggests that, for a given Eh and pH, precipitation of these minerals can occur from ground waters far more dilute in uranium than usually assumed. The relative importance of different uranium compiles as a function of pH was assessed at 25 degrees C and PCO2=10(E+2) or 10(E+2.5) atm for some typical ligand concentrations in ground water (F=0.2 or 0.3 ppm; Cl=10 ppm; SO4=100 ppm; and PO4=0.1 ppm). Complexes were considered "important" if they exceeded 10 percent of the total concentration of uranous or uranyl species. A species is considered "predominant" if it comprises more than half the total of uranous or uranyl species. For uranous ion, calculations showed that fluoride complexes are predominant at pH's below 3-4, and that hydroxyl complexes are predominant at higher pH's. Uranyl ions formed important complexes with fluoride and sulfate at pH's below 4.5-5.5. The fluoride complexes predominated at pH's below about 4. The complex UO2(HPO4)2-2 was surprisingly stable, and was the predominant uranyl species between about pH 4.5 and 7.5. In the absence of phosphate, uranyl carbonate complexes predominate at all pH's above 4.5, but in the presence of UO2(HPO4)2-2 they only predominate above pH 7.5. (JHT)

<93>
Leach, D.L., and L.V. Benson, University of California, Lawrence Livermore Laboratory, Livermore, CA

Hydrogeochemistry of Uranium in the Walker River Basin, California and Nevada. USGS Circular 753; Short Papers of the US Geological Survey Uranium-Thorium Symposium, 1977, J.A. Campbell (Ed.), (pp. 68-70), 75 pp. (1977)

The Walker River Basin lies along the western margin of the Basin and Range province covering an area of approximately 11,000 square kilometers. East Walker River and West Walker River head in the Sierra Nevada Mountains of California, flow through several small valleys, and merge to form the Walker River which terminates in Walker Lake. The entire drainage basin is closed with no outlet to the sea. Granitic, metavolcanic, and metasedimentary rocks of Mesozoic age are the basement rocks of the Walker Basin. Over much of the region they are buried by thick accumulations of Cenozoic sedimentary and volcanic rocks. Most of the exposed basement consists of quartz monzonite or granodiorite. A small number of uraniferous deposits are present along the East Walker River. Uraninite, kasolite, and various secondary uranium minerals occur in three closely related settings: (1) quartz veins in granitic rocks containing silver, lead, copper, and iron sulfides; (2) altered granitic rocks adjacent to quartz veins; and (3) fault gouge zones. Twenty six snow samples were collected from different sites in the east-central Sierra Nevada and 10 were analyzed for uranium. Of these only one sample contained detectable uranium indicating the insignificance of the flux of uranium via precipitation. With the onset of spring, snowmelt is released to the tributary system. Along this segment of the transport path the acidic fluid (pH approximately equal to 5.6) reacts with exposed granite, granodiorite, and felsic volcanics resulting in the release of uranium. In the Sierran headwater region, concentration of uranium was found to be less than 2 ppb; oftentimes only a few tenths of a ppb. In tributaries north of the Sierran headwater region, concentrations in excess of 2 ppb were common, with some as high as 58 ppb, suggesting the presence of a uranium anomaly. The East Walker River has only minor increases in uranium concentration, but the West Walker River show a more significant increase (from 1.8 to 6.4 ppb with increasing transport distance in June). Uranium is an extremely mobile component in the stream waters and does not appear to be effectively removed by interaction with the sediments. In terms of geochemical reconnaissance, tributary water is effective in indicating surficial uranium sources, whereas spring water is effective in locating buried deposits. Streams within the basin may not be effective in locating uranium anomalies, particularly if they receive little ground water input and are modified by reservoirs and irrigation procedures. (JHT)

<94>
Leonova, L.L., V.I. Vernadskii Institute of Geochemistry and Analytical Chemistry, Moscow, USSR

A Luminescent Method of Determination of Small Amounts of Uranium in Igneous. Geochemistry 8:779-787. (1956)

A method for the determination of uranium in small amounts in igneous rocks is described. The method involves a complete decomposition of the rock by fusion with soda and separation of uranium from associated elements in the form of U(HPO4)2 x nH2O on the carrier, zirconium, and the subsequent determination of luminescence of NaF-U beads on the fluorometer FM-42. The method is convenient for use in analyses of rocks and minerals containing less than 1 ppm uranium and for the analysis of water samples requiring great precision. The sensitivity of the method is 5 ppb uranium; its precision is plus or minus 5-10 percent; its speed is 2 to 3 analyses per working day of 6 hours. A faster method for uranium determination in igneous rocks with acid decomposition (HCl + H2O2) and precipitation of uranium as U(HPO4)2 x nH2O on the carrier, zirconium, and with visual determination of luminescence by comparison with standards. This method is applicable to statistical geological investigations where large numbers of analyses are to be handled. The sensitivity of this method is 1 ppm, its precision plus or minus 20 percent. Seven to ten analyses may be carried out per working day of 6 hours. (JHT)

<85>
Leonova, L.L., V.I. Vernadskii Institute of Geochemistry and Analytical Chemistry, Moscow, USSR

Uranium and Thorium in the Variscan Alkalic Intrusives of Southern Tien-Shan (Matcha and Turpi Massifs). Geochemistry 11:925-929. (1964)

The uranium and thorium contents of the alkalic syenite-granite intrusives of Tien-Shan are discussed. The uranium content varies from 0.3 to 9.1 ppm, the thorium content from 2.1 to 38.7 ppm, and the Th/U ratio from 3.2 to 7.0. The late granites contain more thorium and have a higher Th/U ratio than the earlier syenites, possibly as a result of the partial removal of uranium (and thorium) in the carbon dioxide produced during the assimilation of carbonate country rocks by the granitic magma. (JHT)

<86>
Leonova, L.L., V.I. Vernadskii Institute of Geochemistry and Analytical Chemistry, Moscow, USSR

Uranium and Thorium in Hydrothermally Altered Rocks of the Kzyl-Ompul Mountains (Northern Tien Shan). Geochemistry 6:566-571. (1963)

Hydrothermal alteration of the rocks of the Kyzl-Ompul massif resulted in the sericitization of plagioclase, kaolinization and hematitization of potassic feldspar, chloritization of the dark minerals, and the introduction of considerable amounts of uranium into all the rocks. Among the altered rocks, only the syenites of phase I and the related fine-grained syenite dikes were enriched in thorium that was introduced by hydrothermal solutions. It was established that the enrichment of the altered rocks in uranium and thorium did not occur at the same time, but occurred in two stages: thorium was introduced after emplacement of the syenites of phase I and their dikes and uranium was introduced after the emplacement of the leucocratic granites of phase III. This indicates that there is a genetic relation between the hydrothermal solutions enriched in thorium and alkalic rocks and between the solutions enriched in uranium and the silicic rocks. (JHT)

<87>
Leonova, L.L., V.I. Vernadskii Institute of Geochemistry and Analytical Chemistry, Moscow, USSR

Distribution of Thorium in Minerals of the Granites of the Susamyr Batholith (Central Tien-Shan). Geochemistry 6:571-578. (1962)

The distribution of thorium was studied in the minerals present in five samples of granitic rock from the Susamyr batholith. Thorium was present in all the minerals. Its lowest concentrations were found in the salic minerals (4-5 ppm) and its highest were found in allanite (0.7-4.6 percent) and uranothorite (40 percent). The distribution of thorium among the essential minerals of the Susamyr granitoids showed 30 to 40 percent of the total thorium content occurred in the essential minerals and 60-70 percent occurred in the accessory minerals. Among the accessory minerals, allanite [(Ce,Ca,Y)(Al,Fe)3(SiO4)3(OH)] was always the principal concentrator and carrier of thorium in the rocks, generally containing from 50 to 70 percent of the total thorium. Thorium in these granites occurred in three forms: 1) as molecules dispersed through the light-colored minerals (quartz, potassic feldspar, and plagioclase); 2) in solid solution for the rare earths, Zr, and Ca in the accessory minerals (allanite, zircon, sphene, and apatite) and possibly in the dark minerals (biotite, hornblende, etc.); and 3) microscopic crystals of independent Th and U-Th minerals of the uranothorite type. (JHT)

<88>
Leonova, L.L., R.D. Gavrilin, and V.V. Bagreyev, V.I. Vernadskii Institute of Geochemistry and Analytical Chemistry, Moscow, USSR

Behavior of Uranium and Thorium in a Highly Alkalic Intrusive Complex (the Kzyl-Ompul Massif, Northern Tien-Shan). Geochemistry 12:1173-1179. (1961)

The distribution of uranium and thorium in three principal intrusive phases of the Kzyl-Ompul massif was determined by luminescence and colorimetry. The average thorium content of the syenites, quartz syenites, leucocratic granites and alaskites was 50-60 ppm U. There is little variation in the thorium content in the rocks of different phases. The uranium content of leucocratic granites and alaskites (about 6 ppm) is similar to the uranium content of many granites. The uranium content of quartz syenites is near to that of the granites, but the coarsely porphyritic syenites contain twice as much uranium (13.7 ppm) as the younger quartz syenites and granites. The variations in the uranium content within individual phases of the quartz syenites and granites are small and as a rule lie within the limits of analytical error. The content of uranium in syenites varies considerably more from sample to sample, either because of the variable composition of the rocks or because of the irregular distribution of uranium during their crystallization. There is no increase in the uranium and thorium contents in the syenite-granite differentiation series from the older to the younger leucocratic rocks. The rocks of phase I have the highest uranium content, while in the coarsely porphyritic syenites and the younger quartz syenites and granites it is relatively low. The content of thorium is practically constant in all three phases. Such behavior of uranium and thorium is a rare exception to the general tendency of these elements to concentrate towards the end of the differentiation process. The Th/U ratio in the rocks of the massif varies slightly within each phase and increases progressively from 4.5 in syenites to 8.6 in quartz syenites and 9.2 in granites. (JHT)

GEOCHEMISTRY

<89>
Leonova, L.L., and L.S. Pogiblova, V.I.
Vernadskii Institute of Geochemistry and
Analytical Chemistry, Moscow, USSR

Uranium Minerals of the Intrusive Rocks of the
Kzyl-Ompul Mountains (Northern Kirgiziya).
Geochemistry 10:999-1004. (1961)

The distribution of uranium in the minerals of three syenites, three quartz syenites, and an alaskite from the Kzyl-Ompul massif is discussed. The alaskite was characterized by the type of uranium distribution found in granites, with about 50 percent of the uranium being found in the rock forming minerals and the remainder in the accessory minerals. In the syenites, 70 percent of the uranium is contained in the rock-forming minerals. Quartz syenites had an intermediate type of uranium distribution. The same minerals from syenites and granites and alaskite differ considerably in their uranium content, but are constant within a given rock type. Most of the uranium in syenite is immobilized during the first stage of crystallization, so it cannot accumulate in the vein derivatives of the magma. (Auth) (JMT)

<90>
Leventhal, J.S., USGS, Denver, CO

Organic Geochemistry and Uranium in Grants
Mineral Belt. AAPG Bulletin 63(4):691. (1979,
April)

Organic material is closely associated with the primary uranium deposits of the Grants mineral belt. This organic material is now insoluble and nonvolatile, and most of it is lacking in physical structure. The mixture of organic matter and uranium coats sand grains and fills interstices, which seems to indicate that both the organic matter and uranium were introduced as soluble materials after sedimentation. The relation of organic matter and uranium can be shown physically, chemically and statistically. Pyrolysis-gas chromatography, mass spectrometry, and elemental analysis have been used to examine the organic matter from several ore deposits. The results show carbon-rich materials which have been severely degraded by radiation from uranium and daughter products. The organic material now resembles amorphous carbon, having lost most of its hydrogen and oxygen. From the uranium content and approximate age, the radiation dose is calculated to be 10(E+11) rads. The radiation damage has also produced an interesting new carbon-isotope fractionation effect, by which the carbon associated with ore is enriched in carbon-13 relative to the non-ore carbon. Laboratory model experiments using freshly extracted soluble organic material from recent sediments and uranium-as $UO_2(CO_3)_2^{-2}$ show large enrichment of uranium by chelation and ion exchange, which are pH dependent. The greatest concentration factor for uranium is at slightly acid pH values. From model experiments and laboratory work on samples from the Grants district, the following hypotheses are made: first, the soluble organic matter (of unknown origin) coated or precipitated on the mineral grains; subsequently, the uranium-probable as UO_2^{+2} or $UO_2(CO_3)_2^{-2}$ concentrated in and on this organic matter by ion exchange and chelation with functional groups. This cycle of organic coating and uranium concentration could have been episodic or continuous, but must have lasted at least 10(E+6) years based on calculations using assumed porosity, permeability, hydraulic gradient, uranium content of water, and organic concentration factors. Finally, after 10(E+8) years, the radiation damage has created an amorphous carbon material which is deficient in hydrogen and oxygen but which helps protect the ore from mobilizing owing to its chemical inertness. (Auth)

<91>
Leventhal, J.S., J.K. Jennings, and A.J. Lemke,
USGS, Denver, CO

Anomalous Occurrence of Uranium in Alpine Peaks,
Summit County, Colorado and Results of a Simple
Fractionation Procedure. USGS-OFR-78-235; 17 pp.
(1978)

Samples from Summit County, Colorado, were fractionated for analyses of organic content and uranium. The uranium is related to organic content, but not to type or organic matter. In one area, uranium values were around 100 ppm in bulk samples and as much as 200 ppm in certain separated fractions of the samples; this was much higher than the 1-10 ppm normal values for peat. (JMT)

<92>
Lin, N.G., L.N. Morozov, and V.P. Mironov,
Academy of Sciences, Institute of Geochemistry,
Siberian Division, Irkutsk, USSR

Uranium and Thorium in the Paleozoic Granitoids
of the Central Part of the Eastern Sayans (The
Malyy Tagel-Uda Interfluve). Geochemistry
2(1):59. (1965)

Data of 155 analyses of intrusive rocks for Th and U are summarized by rock type and geologic occurrence. The amount of both elements are found to correlate positively with the amount of free quartz in the rocks and with decreasing age of emplacement. The Th/U ratio varies in the opposite sence. Apical parts of the intrusives are richer in both elements and uranium is enriched relative to thorium. Dike rocks are generally similar to their parent rocks in thorium and uranium content. (Auth)

<93>
Lisitsin, A.K., Academy of Sciences, Institute of
Geology of Ore Deposits, Petrography, Mineralogy,
and Geocheeistry, Moscow, USSR

Form of Occurrence of Uranium in Ground Waters
and Conditions of its Precipitation as UO_2.
Geochemistry 9:876-988. (1962)

Ionization constants of uranium in aqueous solution were used to estimate the forms in which uranium occurs in ground water, and the conditions necessary for its precipitation. It was determined that in normal weakly acid, neutral, and weakly alkaline ground waters of different mineralization characteristics, uranium occurs predominantly as uranyl di- and tricarbonate anions. The Eh values calculated for various theoretical compositions in equilibrium with solid UO_2 are in good agreement with appropriate hydrogeochemical data. The Eh value at the beginning of the precipitation of tetravalent uranium from ground waters ranges from approximately 0.0 to -0.2V depending on the concentration of uranium in the solution, the magnitude and character of the salts in the water, its pH, and the concentration of the HCO_3^- ion. The compositon, temperature, Eh, pH, and total uranium content are given for 11 ground waters. (Auth) (JMT)

GEOCHEMISTRY

<94>
Lisitsin, A.K., Academy of Sciences, Institute of Geology of Ore Deposits, Petrography, Mineralogy and Geochemistry, Moscow, USSR

Uranium Content of Oxidizing Petroleums. Geochemistry 7:761-768. (1960)

Uranium in deposits related to altered petroleum is intimately associated with strongly oxidized organic substances of the petroleum series - asphalts, asphaltites, and pyrobitumens. The purpose of this study was to determine the distribution of uranium in petroleum bitumens at the initial stage of their oxidation when they are transformed from light petroleums low in tars and paraffins to heavy, tar-rich oils approaching maltha in physical properties. Petroleums of different compositions from Paleogene deposits in the Fergana basin were used in this investigation. The results of the investigation established a clear relationship between the uranium content in petroleum and its specific gravity, with sharp increases in uranium content as the specific gravity of the petroleums increased. With the increase of specific gravity of petroleum, the concentration of uranium in the ash also increases, reaching tenths of one percent in the heavier varieties. The tendency towards increase in concentration of uranium with increase in the ash content of petroleum is also noticeable, although weaker. This relationship and increase in uranium concentration in ash with increasing specific gravity of petroleum indicate that uranium accumulates in oxidizing petroleum more intensively than in its initial inorganic components. The relationship between uranium content in the ash and the total ash content in petroleum is more complex. In weakly oxidized petroleums, there is a noticeable decrease in uranium concentration in the ash with increase in the ash content. In the more strongly oxidized petroleums, no such regularity is observed. Relatively strongly oxidized heavy petroleum with a high concentration of tar-asphaltene components is capable of extracting uranium from water of different composition with large or small uranium concentrations. Light petroleums with less tar are practically incapable of this. The results of this investigation lead to the conclusion that the main enrichment of petroleums in uranium occurs during oxidation under the action of infiltrating ground water. The capacity of petroleum for extracting uranium from ground waters increases with increase in the degree of their oxidation. The oxidizing petroleums inhibit migration of uranium in ground water, not only indirectly by creating an appropriate environment, but also by direct extraction of it from the waters. (JRT)

<95>
Lovborg, L., H. Wollenberg, Poul Sorensen, and J. Hansen, Danish Atomic Energy Commission, Roskilde, Denmark; Copenhagen University, Institute of Petrology, Copenhagen, Denmark; University of California, Lawrence Berkeley Laboratory, Berkeley, CA

Field Determination of Uranium and Thorium by Gamma-Ray Spectrometry, Exemplified by Measurements in the Ilimaussaq Alkaline Intrusion, South Greenland. Economic Geology 66:168-384. (1971)

Gamma-ray spectrometry in the field was used in connection with an intensive study of the abundance and distribution of uranium and thorium in peralkaline rocks of the Ilimaussaq intrusion of South Greenland. Uranium and thorium were determined from counts accumulated in the 1.76 and 2.62 MeV intervals of a portable gamma-ray spectrometer. Calibrations for uranium and thorium were achieved by use of large concrete standards of known radioelement content, and having a gamma-ray mass absorption nearly equal to that of the rock to be measured. The accuracy of the field gamma-ray spectrometer, depending on standard errors associated with calibration equations, was about 2.5 percent for thorium and ranged from 2.5 to 7.5 percent for uranium, as Th/U varied from 1 to 5. The intensive measurements were made on several types of Nepheline Syenites and Gabbros. Distinct contrasts between uranium and thorium contents of the different rock types within single areas were noted. High uranium and thorium contents in the fine-grained aegirine Nepheline Syenites contrasted with significantly lower values in medium-grained aegirine Nepheline Syenites. Similar contrasts between massive lujavritized gabbro, sheared foliated gabbro, and sheared lujavritized gabbro were also observed. (JHT)

<96>
Ludwig, K.R., C.W. Naeser, and J.T. Nash, USGS, Denver, CO

Uranium-Lead Ages of Uranium Ores From the Midnite Mine, Washington. Proceedings of the Joint Annual Meeting of the Geological Association of Canada, the Mineralogical Association of Canada, and the Geological Society of America, Toronto, Ontario, October 23-26, 1978. The Geological Society of America, Boulder, Colorado, (p. 448), 531 pp. (1978)

The Midnite Mine, located in eastern Washington, is one of the few producing hard-rock uranium deposits in the United States. The ores are localized in phyllites and calc-silicates of the Precambrian Togo Formation, near the contact with a granitic pluton that yields zircon U-Th-Pb ages of approximately 78 million years. Eight high-grade, approximately 500 gram, unoxidized ore samples from drill-core and mine exposures yielded Pb 207/U 235 ages on the narrow range of 50 to 52 million years and define a Pb 207/U 235 isochron age of 51 plus or minus million years. This age coincides with that of the Sanpoil Volcanic, which unconformably overlie the pluton near the mine, and of associated dikes that cut ore. A fission-track age of 69 minus or plus 6 million years on apatite from the granitic pluton in the mine has not been reset and requires that the immediate area not have been heated to more than about 150 degrees C for a long (less than 1 million years) period of time. These data are consistent with pervasive redistribution of uranium into ore zones from an earlier protore by supergene fluids, possibly with thermal of hydrologic influence of overlying volcanic rocks. Pb 206/U 239 ages are lower and more scattered than the Pb 207/U 235 ages, and both types of ages are markedly scattered for very small (less than 1 mg) samples. These systematics reflect migration of both radiogenic Pb and radioactive daughters of U 238, but indicate that the Pb migration is largely restricted to scales of less than 10 cm. The ore minerals are intermixed uraninite and coffinite, with the coffinite occurring somewhat later in the paragenetic sequence. Both ore minerals contain very high concentrations of common Pb (as much as 655 ppm), which may relate to the unusually low degree of radiogenic-Pb migration in these ores. (Auth)

<97>
Ludwig, K.R., and J.S. Stuckless, USGS, Denver, CO

Uranium-Lead Isotope Systematics and Apparent Ages of Zircons and Other Minerals in Precambrian Granitic Rocks, Granite Mountains, Wyoming. Contributions to Mineralogy and Petrology 65:243-254. (1978)

Zircon suites from the two main types of granite in the Granite Mountains, Wyoming, yielded concordia-intercept ages of 2,640 plus or minus 20 million years for a red foliated granite (granite of Long Creek Mountain) and 2595 plus or minus 40 million years for the much larger mass of granite of Lankin Dome. These ages are statistically distinct (40 plus or minus 20 million years difference) and are consistent with observed chemical and textural differences. From the U-Pb-isotope data presented in this paper, a plausible history for the Granite Mountains is as follows: (1) Intrusion of the granite of Long Creek Mountain 2,640 plus or minus 20 m.y. ago into a suite of rocks that had been metamorphosed 2,860 m.y. ago; (2) Intrusion of a much greater mass of granite of Lankin Dome 2595 plus or minus 40 m.y. ago; (3) Deuteric or late-stage metasomatism alteration of zones within this granite shortly after intrusion of the granite of Lankin Dome; (4) Intrusion of diabase dikes; (5) A thermal event between 1,350 and 2,250 m.y. ago which caused a gain of radiogenic Pb by K-feldspars and loss of radiogenic lead from epidotes and apatites; and (6) Uplift and erosion related to Laramide tectonics 50-100 m.y. ago, which resulted in the loss of radiogenic lead by zircon, uranothorite, and apatite, and U loss by epidote and whole rock systems. (JMT)

<98>
Lutts, B.G., and I.G. Mineyeva, Academy of Sciences, Institute of the Physics of the Earth, Moscow, USSR

Uranium and Thorium in Siberian Kimberlites. Geochemistry International 11-12:1278-1281. (1974, October)

Uranium and thorium contents of 10 samples of diamond-bearing and nondiamond-bearing kimberlites were analyzed. Uranium was determined by the luminescence method and thorium was determined by spectrophotometry. Although kimberlites are olivine-bearing ultramafic rocks, their thorium and uranium contents are many times higher than in the other ultramafic and mafic rocks, being comparable to granites in the content of these elements. The high Th/U ratio in kimberlites distinguishes them from all other rocks. The average Th/U ratio for the diamondiferous kimberlites and the nondiamondiferous kimberlites studied was 5.6 and 7.0, respectively. The characteristically high radioelement contents of kimberlites and their anomalous Th/U ratios can be used in prospecting for kimberlite bodies. (JMT)

<99>
Lyons, J.B., USGS, Washington, DC

Distribution of Thorium and Uranium in Three Early Paleozoic Plutonic Series of New Hampshire. USGS Bulletin 1144-F; 43 pp. (1964)

Chemical uranium and thorium data were determined for the calc-alkaline Highlandcroft (Late Ordovician), Oliverian (Middle or Late Devonian) and New Hampshire (Late Devonian) Plutonic Series. Ten rock specimens were chemically and modally analyzed and their constituent minerals analyzed chemically for uranium and thorium and spectrochemically for minor elements. All series showed normal radioactivities, with progressive increases in uranium and thorium with increased content of felsic minerals, and no marked trends and Th/U ratios. Highlandcroft rocks showed a range of 2.6-5.0 ppm uranium and 10.6-14.8 ppm thorium; Oliverian rocks had 0.6-15.9 ppm uranium and 2.9-57 ppm thorium; New Hampshire rocks showed 1.5-39 ppm uranium and 2.9-29.5 ppm thorium. Pegmatites have abnormally low thorium to uranium ratios, and aplites have high but variable uranium and thorium contents. High uranium and thorium contents accompanied high SiO2 and K2O and low CaO contents in the rocks. The Highlandcroft and Oliverian Series, both of which are regionally metamorphosed, had as much as 67 percent of the uranium and 79 percent of the thorium held by sphene and epidote. Both minerals were absent or rare in the higher temperature unmetamorphosed New Hampshire Series, in which monazite and xenotime are characteristic accessories, and in which most of the uranium and thorium was dispersed in the major silicates. Enrichment of the plutonic residua in elements rejected by early crystallized silicates appears to be the simplest and best explanation of the uranium and thorium distribution patterns seen in these rocks. (JMT)

<100>
Manskaya, S.M., and L.A. Kodina, V.I. Vernadskii Institute of Geochemistry and Analytical Chemistry, Moscow, USSR

Aromatic Monomers of Lignin in Lignites and Their Possible Role in the Concentration of Uranium, Germanium, and Vanadium. Geochemistry 4:389-401. (1963)

Samples of wood that had been buried in peat for 500 to 3000 years and Tertiary lignites were studied using ethanolysis, paper chromatography, and ultraviolet spectrophotometry. Quantitative determinations were made of the content of vanillin and vanilloylmethylketone in wood in various stages of decomposition, and in the lignin and humic acids extracted from the samples. Lignin undergoes profound changes after burial. The process of alteration is accompanied by the partial destruction of the polymeric structure of lignin and the liberation of phenylpropane monomers. These monomers for humic acids, and serve as the basis of condensed structures that are caused by the additional bonding between the carbon atoms of propane chains. Germanium, uranium, and vanadium accumulate most intensively in lignites in the early stages of decomposition of wood by reaction with active groups of aromatic lignin structures. When these structures become condensed later, they hold the trace metals much more firmly but do not accumulate more metals. (Auth) (JMT)

<101>

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<101>
Millard, H.T., Jr., USGS, Washington, DC

Determination of Uranium and Thorium USGS Standard Rocks by the Delayed Neutron Technique. USGS Professional Paper 840, (pp. 61-65), 192 pp. (1976)

Uranium and thorium were determined in 12 USGS standard rocks by the delayed neutron technique. Duplicates from three bottles of each standard rocks were analyzed in random order. The averages are: AGV-1, 2.05 ppm U and 5.37 ppm Th; BCR-1, 1.81 ppm U and 5.26 ppm Th; BHVO-1, 0.48 U and 0.90 Th; G-2, 2.15 ppm U and 24.0 ppm Th; GSP-1, 2.56 ppm U and 106.9 ppm Th; MAG-1, 2.82 ppm U and 12.2 ppm Th; QLO-1, 2.01 ppm U and 3.28 ppm Th; RGM-1, 5.95 ppm U and 13.1 ppm Th; SCO-1, 3.15 ppm U and 9.52 ppm Th; SDC-1, 3.12 ppm U and 11.4 ppm Th; SGR-1, 5.60 ppm U and 7.66 ppm Th; and STM-1, 9.10 ppm U and 26.6 ppm Th. The thorium and uranium contents of the bottles of samples, except SCO-1, may be accepted as homogeneous at P (0.95). The uranium content of SCO-1 may be declared heterogeneous at P (0.95) or accepted as homogeneous at P (0.95). (Auth)

<102>
Mitchell W.S., M. Zentilli, and K.A. Taylor, Canada Geological Survey, Ottawa, Ontario, Canada; Dalhousie University, Department of Geology, Halifax, Nova Scotia, Canada

Distribution of Uranium in an Active Geothermal Area in the Azores. Geological Survey of Canada Paper 77-1B, Report of Activities, Part B, (pp. 137-139), 353 pp. (1977)

Seventy-two samples taken from a 981 m borehole on the island of Sao Miguel, Azores were analyzed by the fission tract method for homogenized whole-rock uranium concentration. Uranium variations through a single flow unit were also investigated with a further 14 whole-rock U-analyses and distributions within several porphyritic basaltic units were mapped. The average U concentration in basits was found to be 1.33 ppm, slightly higher in coarse flows (1.57 ppm) and brecciated portions of flows (1.53 ppm). Pillow basalts contain an average of 2.12 ppm U, and trachytes average even higher (4.78 ppm). These concentrations, which are an order of magnitude greater than those of oceanic tholeiites (0.10-0.29 ppm) or Bermuda basalts (0.18 ppm), may be due to the alkalic nature of the Azores basalts or to hydrothermal enrichment. The relatively high U concentrations found at flow boundaries are believed due to migrating hydrothermal fluids, whether by introduction of U to the system or by its redistribution. There is evidence that U is strongly concentrated by weathering in the oxidized tops of subaerial flows (5.51 ppm average). (LKM)

<103>
Moore, S.C., and N.G. Lavery, Exxon Minerals Company, Albuquerque, NM; Exxon Minerals Company, Houston, TX

Magnitude and Variability of Disequilibrium in San Antonio Valley Uranium Deposit, Valencia County, New Mexico. AAPG Bulletin 63(4):691-692. (1979, April)

The San Antonio Valley deposit is a flat-lying tabular body of uranium mineralization in the Westwater Canyon Member of the Morrison Formation. The deposit is elongate northwest-southeast, is approximately 1.6 km long and 0.3 km wide, and averages from 2 to 8 m in thickness. The "trend-type" deposit has a chemically reduced mineralogy and occurs below the water table. The average disequilibrium factor for the deposit shows a 8 percent enrichment in chemical uranium. Variations occur throughout the deposit, however, with the northeastern edge being chemically excessive by 11 percent and the southwestern edge being chemically deficient. Three ore-reserve correction factors have been assigned, one to each of three longitudinal zones. The use of multiple correction factors will optimize mine planning and uranium recovery. Vertical profiles of radiometric and assay data through ore zones show dispersion of daughter isotopes away from uranium concentrations. Horizontal data plots show removal of daughter isotopes from the northeastern edge of the deposit and fixation of daughter isotopes in the central and southwestern parts of the deposit. Local loss of uranium is also suggested in the central and southwestern parts of the deposit. It is hypothesized that recent groundwater flow from east to west has redistributed the isotopic species. This flow system caused both the local vertical migration of daughter isotopes and also the transport of daughter isotopes and uranium in the direction of the hydrologic gradient. These conclusions are based wholly on chemical and gamma-equivalent uranium assays. (Auth)

<104>
Mubarakmand, S., P. Chaudhry, and F.I. Nagi, Nuclear Research Laboratory, Government College, Lahore, Pakistan

Absolute Determination of Uranium Concentration in Rocks by Gamma-Ray Spectroscopy. Nuclear Instruments and Methods 140:133-135. (1977, January)

A method for the measurement of uranium concentration in ore samples is presented. The 93 keV gamma rays emitted by the first decay product Th-234 are resolved using a 40 cubic centimeter Ge(Li) detractor. The activity due to this gamma ray is measured. Th-234 is selected for measurement of its gamma activity because it is in equilibrium with its parent and this directly leads to information on the quantity of U-238 in the sample. (Auth)

GEOCHEMISTRY

<105>
Murphy, M., W. Wollenberg, H. Strisower, H. Bowman, S. Flexser, and I. Carmichael, Lawrence Berkeley Laboratory, Earth Sciences Division, Berkeley, CA

Uranium in Alkaline Rocks. LBL-7029; GJBX-78(78); 105 pp. (1978, April)

Alkaline igneous rocks are characterized by the presence of feldspathoids and/or alkali-pyroxenes and alkali-amphiboles. These rocks are divided into two broad categories: (1) miaskitic rocks and (2) agpaitic rocks. In miaskitic rocks, the sum of the potassium and sodium contents is less than the aluminum content of the rock; in agpaitic rocks this trend is reversed. In this study geologic and geochemical criteria were developed for the occurrence of economic uranium deposits in alkaline ingeous. Sixty nine locations having alkaline igneous rocks were disclosed during a literature search. The rocks were nepheline syenites, alkaline granites, and carbonatites. A ranking system identified ten of the sites as the most likely to have uranium resource potential. (JST)

<106>
Nagasawa, H., and H. Wakita, Gakushuin University, Mejiro, Toshima-ku, Tokyo; Japan Atomic Energy Research Institute, Radioisotope School, Honkomagome, Bunkyo-ku, Tokyo, Japan

Partition of Uranium and Thorium between Augite and Host Lavas. Geochimica et Cosmochimica Acta 32:917-921. (1968)

Uranium and thorium concentrations were determined in pairs of samples representing a liquid and a solid phase under possible partition equilibria, such as groundmass of a volcanic lava and Ca-rich clinopyroxene (augite) crystals separated from it. In addition, the partition of uranium and thorium between Ca-rich clinopyroxene (diopside), orthopyroxene and olivine coexisting in a peridotite was determined. From the data derived from this experiment, it was found that Th and U were enriched in clinopyroxene (diopside) by a factor of 10 to 20 compared with orthopyroxene (enstatite) in the same peridotite samples. On a basis of ionic substitution, the enrichment of thorium and uranium could be accounted for by the substitution of Ca^{+2} (0.97 Angstroms) by Th^{+4} (1.06 Angstroms) and U^{+4} (1.01 Angstroms) ions. Th/U ratios were greater in the groundmess than in the augite phenocryst of the lava. (JHT)

<107>
Naumov, G.B., Academy of Sciences, V.I. Vernadskii Institute of Geochemistry and Analytical Chemistry, Moscow, USSR

Some Physiochemical Characteristics of the Behavior of Uranium in Hydrothermal Solutions. Geochemistry 2:127-147. (1961)

The characteristics of pitchblende parageneses are reviewed, leading to the conclusion that carbon dioxide, fluorine, sulfur, chlorine, and some form of silica were important components of uranium-bearing hydrothermal solutions. The solutions could not have been strongly acid, and the temperatures were in the range of 25 to 300 degrees C at pressures of less than 1000 atmospheres. The study of the physicochemical characteristics of the behavior of uranium in such systems showed that uranium could be transported in the form of complicated complex ions, among which complex carbonate and fluoride ions are the most probable. Most uranium is probably transported in the hexavalent form as complexes, and is deposited (and reduced) when the complexes are destroyed. The factors causing deposition of pitchblende are considered in detail in the article.
(Auth) (JST)

<108>
Naumov, G.B., and O.F. Mironova, V.I. Vernadskii Institute of Geochemistry and Analytical Chemistry, Moscow, USSR

Oxidation-Reduction Equilibrium in the System Uranium-Iron in a Carbonate Environment and its Significance to Geochemistry. Geochemistry 3:286-293. (1960)

Under certain conditions, it is probable that iron will have a regular effect on the valence state of uranium and, thus, on its migration in the crust of the earth. In an acid environment, in the absence of noticeable complex formation, the equilibrium in the system: $UO_2^{+2} + 2Fe^{+2} + 4H^{+} = U^{+4} + 2Fe^{+3} + 2H_2O$ is strongly shifted to the side of oxidation of uranium and reduction of iron. In an alkaline medium, however, the uranium and iron are present as hydroxides and the equilibrium is shifted to the side of reduction of uranium and oxidation of iron. For example, in a carbonate solution in equilibrium with precipitate containing oxides and carbonates of trivalent and bivalent iron, almost all uranium will be present in the hexavalent state. Since it is known that many uranium deposits were formed from carbonate hydrothermal solutions, interaction of the uranium-bearing carbonate solution and rocks containing hematite would result in hexavalent uranium in the ores because no important concentrations of tetravalent uranium could form. Carbonate solution passing through rocks containing hematite and uranium may become enriched in uranium not only by extracting hexavalent uranium, but by oxidizing the tetravalent form to the hexavalent state. Such reactions may also occur in the ore-bearing zones themselves. An increase in the concentration of carbonate ions may lead to the oxidation and solution of already precipitated pitchblende and a decrease, to the precipitation of UO_2. Redeposition and even impoverishment of uranium ores may be governed by the carbon dioxide regime. (JHT)

<105>

GEOCHEMISTRY

<109>
Neuschel, S.K., C.M. Bunker, and C.A. Bush, USGS, Washington, DC; USGS, Denver, CO

Correlation of Uranium, Thorium, and Potassium with Aeroradioactivity in the Berea Area, Virginia. Economic Geology 66(2):302-308. (1971, March)

In the Berea area, Virginia, a small quartz monzonite pluton intrudes chlorite-actinolite schist and is overlapped by Coastal Plain sand and gravel deposits. A detailed aeroradioactivity survey of the area shows unusually high radioactivity (1,150 counts/second) over the quartz monzonite. A total of 22 auger samples were taken across all formations to a depth of 2 to 3 feet, and radioelement concentrations were determined by gamma-ray spectrometry. There is a general direct correlation of high radioactivity with increase in radioelement concentrations. Abundances of uranium and particularly thorium in the quartz monzonite are two and three times the average for rocks of this type. The major contributions to the aeroradioactivity intensity from the pluton are from uranium and its daughter products, although all radioelements emit measurable radiation. (Auth) (JST)

<110>
Nishimura, S., University of Osaka Prefecture, Department of Geological Sciences, Sakai, Osaka, Japan

Disequilibrium of the U-238 Series in Recent Volcanic Rocks. Earth and Planetary Science Letters 8:293-300. (1970)

Concentrations of U-238, Th-230, and Ra-226 are given for recent volcanic rocks from various regions. Disequilibrium observed among U-238 series is interpreted in terms of chemical fractionations occurring during magmatic processes. The fractionation pattern Ra greater than or less than Th greater than U is observed in Hawaii, the Azores, and Japan in oceanic and island arc volcanic regions. The pattern Th less than U is seen in the Caucasus, Kamchatka, and Italy for continental volcanic regions. (Auth) (JST)

<111>
Nishimura, S., Kyoto University, Institute of Earth Science, Kyoto, Japan

Partition of Uranium Between Peridotite Nodules and Host Basalt. Chemical Geology 10:211-221. (1972)

Contents of uranium in mineral fractions from some basic rocks and peridotite nodules were measured. The peridotite nodules ranged in uranium content between 4.8 x 10(E-2) to 8.2 x 10(E-3) ppm. Uranium content in the olivines ranged between 4.8 x 10(E-2) to 1.2 x 10(E-3) ppm. These values reflect the chemical fractionation that occurred in the magmatic processes. (Auth)

<112>
Nkomo, I.T., and J.N. Rosholt, USGS, Denver, CO

A Lead-Isotope Age and U-Pb Discordance of Precambrian Gneiss from Granite Mountains, Wyoming. USGS Professional Paper 800-C, Geological Survey Research 1972, (pp. C169-C177), 281 pp. (1972)

Lead isotopic composition and concentration in six paragneisses, a granitic gneiss, and two granites from the Granite Mountains were determined on whole-rock samples and seven associated feldspars. Uranium and thorium contents were also determined for the whole rock and three of the feldspar samples. The Pb 207/Pb 204 versus Pb 206/Pb 204 data from the whole rock samples yielded a date of 2,950 plus or minus 120 million years for the gneiss. This date was in excellent agreement with a Rb/Sr date of 2,950 plus or minus 80 million years obtained previously and it may indicate the time of metamorphism of these rocks. The uranium-thorium incorporation into the crustal system was probably a contemporaneous occurrence. Because the crystallization of massive biotite granite probably occurred some 2,790 million years ago, the gneiss cannot be regarded as cogenetic with the granite. Lead-uranium and lead-thorium relations show marked discordance and cannot be used to calculate ages. In the whole-rock samples, uranium loss seems to have predominated during the Cenozoic. (JST)

<113>
Osipov, D.K., and R.S. Zhuravlev, Academy of Sciences, Institute of Geology and Geophysics, Siberian Division, Novosibirsk, USSR

Uranium and Thorium in the Igneous Rocks of the Kuzbas. Geochemistry 2(3):479-485. (1965)

The extrusive rocks of the Kuzbas are characterized by relatively uniform distribution of uranium and thorium. Upper Paleozoic trachyandesites and trachybasalts contain, on the average, 3.77 ppm uranium and 13.4 ppm thorium. The Th/U ratio is 3.6. The Lower Mesozoic basalts on the Tom' River contain 2.66 ppm uranium and 9.48 ppm thorium, and on the Nizhnyaya Ters' River they contain 3.12 ppm uranium and 13.20 ppm thorium. The Th/U ratio ranges from 3.6 to 4.2. In the trachyandesites and trachybasalts the bulk of the uranium and thorium is held in feldspars. In the basalts, the uranium and thorium is concentrated in the glassy mesostasis. There was a positive correlation between uranium and thorium and these elements were positively correlated with SiO_2 and K_2O and negatively correlated with CaO and MgO. (JST)

GEOCHEMISTRY

<114>
Osmond, J.K., and J.B. Cowart, Florida State University, Geology Department, Tallahassee, FL

The Theory and Uses of Natural Uranium Isotopic Variations in Hydrology. Atomic Energy Review 14(4):621-679. (1976)

> The dissolved concentration of uranium and the relative abundance of two uranium isotopes, U 234 and U 238, vary over a wide range of values in natural waters. The concentration is controlled mainly by the redox potential of the environment and by CO2. The mechanism of isotope fractionation is thought to be entrainment of U 234 in the aqueous phase either by selective leaching of the solid phase or by direct recoil of the daughter nuclide. Ion exchange techniques and alpha-spectrometry permit the measurement of uranium at concentrations as low as pp 10(E+11) and the isotopic ratio to a few percent. In oxidizing conditions the uranium isotopes behave in a chemically stable conservative manner such that separate groundwater sources may have identifiably different characteristics and mixing volume calculations may be made. Other potential uses of these isotopes include radiometric dating, tracing of hydrologic systems, ore prospecting and earthquake prediction. (Auth)

<115>
Ostrom, M.E., R.E. Hopkins, W.A. White, and L.D. McVicker, Illinois Geological Survey, Urbana, IL

Uranium in Illinois Black Shales. Illinois Geological Survey Circular 203; 15 pp. (1955)

> 175 samples of dark gray to black shale were taken from outcrops in 44 Illinois counties. The highest percent equivalent uranium, determined by radiometric assay, of any of the samples was 0.17 (in Gallatin County). The uranium oxide of 15 of the samples having the higher percent equivalent uranium ranged between .001 and .018. The uranium oxide averaged .002 percent lower than the percent equivalent uranium for these 115 samples. Phosphatic nodules and bands found in relatively small quantities in some black shale gave a higher percent equivalent uranium than the shales in which they occur. The maximum uranium oxide content of the phosphatic materials investigated was 0.75 percent. (Auth) (NPW)

<116>
Overstreet, W.C., A.M. White, and J.J. Warr, Jr., USGS, Denver, CO

Uranium-Rich Monazites in the United States. USGS Professional Paper 700-D, Geological Survey Research 1970, (pp. D169-D175). (1970)

> Uranium-rich monazites in the United States (defined here as being 0.95 percent or more U3O8) have been found only in parts of the Inner Piedmont province of North and South Carolina. These monazites are derived predominantly, if not entirely from granitic rocks and associated pegmatites that range in age from Ordovician to Permian. The most common sources of these uranium-rich monazites are the syntectonic Toluca Quartz Monzonite of Ordovician age and the post-tectonic Cherryville Quartz Monzonite of Mississippian to Permian age. The latter is the source of the most uraniferous monazite known in the United States; 2.34 percent U3O8. The analyzed monazites in this report are predominantly from stream placers, and they cannot be related positively to their source rocks. (JHT)

<117>
Pavshukov, V.V., L.V. Komlev, Ye. B. Anderson, and I.G. Sayslova, All-Union Geological Research Institute, Leningrad, USSR

X-Ray Microprobe Data on the State of the U-Pb System in Uranium Ores. Geochemistry International 12(2):251-261. (1975)

> Uraninite retains radiogenic lead in the absence of superimposed processes, evidently because the lead is chemically bound in the lattice. Radiogenic lead in uranium minerals of the coffinite and brannerite type is partially lost by diffusion and is sorbed by sulfide minerals. As a result of this, it is undesirable to isolate monomineralic fractions of these minerals for isotope age determinations. (Auth)

GEOCHEMISTRY

<118>
Pierce, A.P., and J.N. Rosholt, Jr., USGS, Denver, CO; USGS, Miami, FL

Radiation Damage and Isotopic Disequilibria in Some Uranium-Bearing Asphaltite Nodules in Back-Reef Dolomites, Carlsbad, New Mexico. USGS Professional Paper 424-D; Geological Survey Research 1961 - Short Papers in the Geologic and Hydrologic Sciences, Articles 293-435, (pp. 320-323). (1961)

Uraniferous asphaltite nodules (asphaltite-filled vugs) have been studied in late Permian age marine carbonate-evaporite rocks of the Yates and Seven River Formations from the Rocky Arroyo area near Carlsbad, New Mexico. Distribution correlates well with that of asphaltic sandstones which transgress the back-reef facies changes of Capitan Reef and probably served as channels for mineralizing solutions. They may be responsible for abnormally high radioactivities logged along the flanks of the Delaware Basin north of Rocky Arroyo. A feature of the area is the abrupt lateral change in lithology from gypsum, red shale, and sandstone on the west to bituminous marine dolomite on the east. The facies change occurs progressively eastward in younger formations, and has acted as an important geochemical control on mineralization. Asphaltite nodules near the facies contact are surrounded by pyrite and marcasite; those at greater distances show only traces of sulfide. Distribution of asphaltite in the Rocky Arroyo area is locally controlled by fractures, bedding planes, stylolites, and fossil molds. U content is greatest near the center of the nodules. Apparent ages based on lead, lead isotope, and uranium analyses range from 203 to 270 million years depending on the process. Radiation damage in the organic phase of the nodules suggests they were fluid for a relatively long period - probably during the first 10-20 percent of their existence. Mineralizing sulfate solutions may have migrated laterally through the sandstones from the evaporite facies, and ascended through fractures into the petroliferous back-reef dolomite. Distribution of U shows that it could have been deposited gradually from surrounding solutions; this may account for the discordant isotopic ages. Thermoluminescence and isotope data indicate U and daughter products have been lost to the surrounding dolomite during at least recent history. Thermoluminescent halos surround the nodules, with an average width of 1.5 mm. With the exception of Th 230, U and Ac series daughters are impoverished in the nodule but enriched in the halo. This is interpreted as indicating (a) geologically recent U migration into the surrounding rock or (b) steady migration of daughter products into the surrounding rock. (LKH)

<119>
Place, J.T., N.M.R. Della Valle, and D.G. Brookins, Gulf Mineral Resources Company, Albuquerque, NM; University of New Mexico, Albuquerque, NM

Mineralogy and Geochemistry of Mariano Lake Uranium Deposit, Smith Lake District, New Mexico. AAPG Bulletin 63(4):692. (1979, April)

The Mariano Lake uranium deposit is located on the west side of the Smith Lake district of the Grants mineral belt. Mineralization is restricted to a basal arkosic sandstone of the Brushy Basin Member of the (Jurassic) Morrison Formation. This sandstone, called the Poison Canyon sandstone (economic usage), consists of a sequence of paleochannels in which mineralization has been deposited in a roll-type tabular deposit. This roll front is directly related to an oxidation-reduction interface. Chemically, the deposit is somewhat different from other Grants mineral belt deposits. Calcium and CO3 content are low, but V, Ba, and S are relatively abundant. Sulfur found in pyrite is also possibly associated with uranium sulfates. Titanium is found as a secondary oxide, derived from titanomagneties of the originally deposited mineral assemblage. Molybdenum, arsenic, and other trace elements show a regular zoning across the deposit, but cerium is slightly depleted. The mineralogy of the Mariano Lake deposit includes abundant disseminated pyrite in mineralized reduced areas and hematite in the oxidized barren areas. Calcite, barite, gypsum, and jordisite are rare. Clay mineralogy includes kaolinite, chlorite, illite, and mixed layer illite-montmorillonite. Contrary to what has been found in other deposits of the Grants mineral belt, zonation of the clays is reversed, with kaolinite being more abundant in the downdip reduced sediments. The phenomenon is thought to be the result of backwash off the south-dipping flank of the Mariano anticline. (Auth)

<120>
Pluman, I.I., Academy of Sciences, Institute of Geology and Geophysics, Siberian Division, Novosibirsk, USSR

Uranium Content of the Upper Jurassic Black Bituminous Argillites of the West Siberian Plate. Geochemistry International 8(6):845-851. (1971)

The uranium content in the Upper Jurassic black bituminous argillites of the West Siberian plate was determined from gamma-ray logs taken from more than 200 wells drilled during the exploration for petroleum and natural gas. The logs were analyzed quantitatively and the results were confirmed by luminescence analysis for uranium. The sedimentary beds studied were mainly dark-gray and black, slightly calcareous, platy argillites rich in organic matter (up to 10 percent). Abundance of phosphatized fish remains indicated the argillites had been deposited in a marine basin. Sapropel derived from plankton is the major component of the organic matter. Pyrite was abundant in the argillites, occurring as microscopic globules and segregations. The relatively high radioactivity of the black argillites is mainly related to their uranium content. The highest uranium concentrations were found in the argillites with the highest content of organic matter. The thorium content ranged from 5 to 10 ppm and there was almost no increase in the black argillites. The content of mobile, leachable uranium in the argillites did not exceed 2 ppm, with the rest occurring in a relatively insoluble form bound to organic matter and phosphatized fish remains. According to the luminescence analysis, fish bones contained between 1000 and 3000 ppm uranium and fish scales averaged 200 ppm uranium. The uranium accumulated in the black argillites during their deposition as a result of abundance of organic matter in the sediments and conditions favorable for the precipitation of uranium from the water. Reducing conditions created by the generation of hydrogen sulfide in the deeper part of the basin played an important role in the precipitation of uranium from the sea water. (JMT)

GEOCHEMISTRY

<121>
Plcman, I.I., Academy of Sciences, Institute of Geology and Geophysics, Siberian Division, Novosibirsk, USSR

Uranium Content in the Upper Jurassic Black Argillites of the West Siberian Plate as a Criterion of Geochemical Conditions of Sedimentation. Geochemistry International 8(5):716-721. (1971)

In this paper geochemical data from oceanographical investigations are used in reconstructing the geochemistry of the Upper Jurassic Bazhenov Formation in West Siberia. The Bazhenov Formation is a series of black argillites characterized by a high (3-18 percent) sapropelic carbon and pyrite (1-15 percent) contents. Uranium content ranges from 1 X 10(E-3) percent to 7 X 10(E-3) percent; averages for other rocks of the region are less than 5 X 10(E-4) percent. There is a pronounced correlation between organic carbon and uranium, which is not found in the carbon-rich rocks of lower-middle Jurassic and Cretaceous age in the area. Th/U ratios are generally less than 1 for the black argillites, 2-3 or more for the other sedimentary rocks. The geochemical characteristics of the Bazhenov argillites are very similar to those of modern Black Sea sediments from the hydrogen sulfide zone, which are also enriched in sapropelic carbon, sulfur, and uranium, and in which the Th/U ratio is less than 1 (oceanic sediments have Th/U ratios of 4-25), is concluded that the Upper Jurassic argillites or the West Siberian plate were depicted in a euxinic basin. (LKH)

<122>
Polyakov, A.I., and G.A. Kot, V.I. Vernadskii Institute of Geochemistry and Analytical Chemistry, Moscow, USSR

Distribution of Thorium Among the Minerals of Nepheline Syenites of the Lovozero Massif. Geochemistry International 2(1):47-58. (1965)

Chemical analyses for Th in mineral separates, material-balance calculations, autoradiographic studies, and leaching experiments showed thorium in all minerals separated from the nepheline syenites of the Lovozero massif. There were two types of concentrations of the thorium in these rocks: (1) in accessory minerals, such as loparite and eudialyte, crystallized during the magmatic stage; and (2) in submicroscopic segregations of late formed minerals and in dispersions in the essential minerals. The thorium occurring in these submicroscopic inclusions and in the essential minerals is easily leached out with a 2 percent solution of ammonium oxalate. Thorium dispersed in the essential minerals does not appear to enter their crystal structures. In the early stages of a crystallizing melt, it is possible for thorium to be withdrawn, in which case, it substitutes for the rare earths in the structures of loparite, eudialyte, and rinkolite in urtites and lujavrites. If the thorium is not withdrawn early in the history of the melt, it may accumulate in the residual magma and pass into the solid phase during the late postmagmatic stage of crystallization. In this case, it is bound in submicroscopic inclusions of radioactive minerals. (JHT)

<123>
Polyakov, A.I., and O.P. Sobornov, V.I. Vernadskii Institute of Geochemistry and Analytical Chemistry, Moscow, USSR

Uranium, Thorium and Potassium in the Volcanic Rocks of Iceland. Geochemistry International 12(5):20-27. (1975)

The distribution of uranium, thorium, and potassium in Neogene-Quaternary volcanic rocks of Iceland was investigated by gamma-ray spectrometry. The radioelement content of the Tertiary plateau basalts of Iceland corresponded to the content of the radioelement in the platform basalts. The young rift basalts are characterized by considerable variation in the content of radioelements: the alkali olivine basalts are rich in these elements, while tholeiites have lower uranium, thorium, and potassium contents than the oceanic tholeiites. The content of uranium, thorium, and potassium in the Holocene basalts of Iceland is inversely proportional to the volume of basaltic melts from which they crystallized. Mantle rocks are the source of the radioelements. The content of radioelements in the basalt-rhyolite series depends on the alkali content in the melt. Accumulation of radioelements in the felsic differentiates corresponds to separation of 5-10 percent of the rhyolite eutectic. There is significant positive correlation among the radioelements and between them and silica. (JHT)

<124>
Polyakov, A.I., and M.P. Volynets, V.I. Vernadskii Institute of Geochemistry and Analytical Chemistry, Moscow, USSR

Distribution of Thorium in a Series of Ultrabasic Alkalic Rocks of the Kola Peninsula. Geochemistry 5:446-454. (1961)

Thirty-two determinations of thorium in rocks and minerals of three co-magmatic ultrabasic alkalic massifs of the Kola peninsula were done by the ion exchange-colorimetric methods. It was found that the thorium content in the rocks of the ultrabasic alkalic series was relatively high as compared with the normal basic and ultrabasic rocks. The thorium content is a single series of ultrabasic alkalic rocks increased in the course of magmatic differentiation, paralleling an increasing content of a number of other lithophilic elements. The highest concentration of thorium was found to form during the pegmatitic and pneumatolytic stages. The content of the thorium in the accessory minerals from ultrabasic alkalic rocks was closely related to the total content of this element in the rocks. The thorium content in the ultrabasic alkalic series of rocks may serve as a geochemical indicator of the detree of magmatic differentiation. (JHT)

<125>
Porritt, R.E.J., and S.J. Bone

Determination of Uranium in Ores by Radiometric Assay. Analytical Chemistry of Uranium and Thorium, Proceedings of a Symposium, Lucas Heights, Sidney, Australia, May 7-8, 1970. Australian Atomic Energy Commission, Sidney, (pp. 2.1-2.12), 102 pp. (1970)

Beta and gamma radiations emitted by the naturally-occurring radionuclides are only suitable for radiometric assay. The beta-gamma method and gamma spectrometry are the most suitable for routine determination of the uranium content of ore. The beta-gamma method estimates the uranium from the beta activity emitted by the decay chain between U 238 and RA 226. If thorium is present its contribution is automatically allowed for but the method does not correct for significant activity contributed by other isotopes. The gamma spectrometric method directly indicates the state of radioactive equilibrium, and corrects for any disequilibrium observed between U 238 and Ra 226. The method reveals the presence of thorium and can allow for its contribution to the assay. Interfering activities from other isotopes can also be identified. Of the two methods due gamma spectrometric method has a greater precision and lower detection limit. (PAG)

<126>
Price, V., R.B. Ferguson, and E.I. Baucom, Savannah River Laboratory, Analytical Chemistry Division, Aiken, SC

SRL Hydrogeochemical and Stream Sediment Reconnaissance - Raw Data Release III - Orientation Study in the Williamsport, Pennsylvania, Area. GJBX-53(76); DPST-76-141-3; 78 pp. (1976, September)

Data is presented for 66 surface sites and 67 ground water sites in the Williamsport quadrangle other than the Sonestown 7 1/2' quadrangle. Data is also presented for 38 surface sites and 23 ground-water sites in the Sonestown 7 1/2' quadrangle. Tabular data for each site include alkalinity; conductivity; temperature; pH; dissolved oxygen; Eh; sulfate, nitrate, and phosphate ions; ammonia; site descriptors; and analyses for supplementary elements. (PAG)

Data from the Sonestown 7 1/2' quadrangle may duplicate data presented by A.W. Rose, M.L. Keith, and N.H. Suhr in "Geochemical Drainage Surveys for Uranium: Sampling and Analytical Methods Bases on Trial Surveys in Pennsylvania," GJO-1645-1 and GJBX-28(76).

<127>
Price, V., R.B. Ferguson, and E.I. Baucom, Savannah River Laboratory, Analytical Chemistry Division, Aiken, SC

SRL Hydrogeochemical and Stream Sediment Reconnaissance - Raw Data Release IV-Orientation Study in the Kings Mountain, North Carolina, Area. GJBX-66(76); DPST-76-141-4; 84 pp. (1976, November)

Ninety-nine surface sites and ninety-six ground-water sites were samples over an 800-square-mile area. Uranium concentrations ranged from 2 to 156 ppm in sediment and from 5 to 186,000 ppt in water. Symbol plots showing areal distribution of uranium and cumulative frequency plots of uranium concentrations in ground water, stream water, and stream sediment are presented. Tabular data for each site include temperature; alkalinity; conductivity; pH; dissolved oxygen; Eh; sulfate, nitrate and phosphate ions; ammonia; site descriptors; and analyses for 27 supplementary elements in sediment. (Auth) (PAG)

<128>
Rafalsky, R.P.

The Experimental Investigation of the Conditions of Uranium Transport and Deposition by Hydrothermal Solutions. Peaceful Uses of Atomic Energy, Vol. 2, Survey of Raw Material Resources, Proceedings of the 2nd International Conference, Geneva, Switzerland, September 1-13, 1958. United Nations, New York, (pp. 423-488), 843 pp. (1958)

Experimental data obtained from this investigation confirmed the possibility of the transport of hexavalent uranium by hydrothermal solutions and its deposition as result of the reduction process. The solubilities of its compounds are high enough to provide for its intensive migration under hydrothermal conditions. It has also been proved that, at elevated temperatures and pressures, uranium is reduced by ferrous iron and bivalent sulfur present in natural minerals or in solution. In addition, it was ascertained that an alkaline medium is less favorable for reduction than an acid one. The data available do not yet make it possible to draw a conclusion that considerable deposits of original uranium ores could be formed by the reduction and precipitation of uranium from alkaline solutions. On the contrary, the rate of reduction is sufficiently high in acid medium over a wide range of pH values. It should be stressed that in numerous experiments for the reduction of uranium, no visible nodules of pitchblende were observed on any occasion. Crystals of uraninite or amorphous precipitates, however, did form. Of considerable interest was the fact that pitchblende is often found in close association with sulfides. This is regarded as an evidence of simultaneous deposition of the minerals. These facts lead to a conclusion that, in hydrothermal solutions, uranium has been transported in its tetravalent form, for based on the results of the experiments, it can hardly be assumed that the uranyl ion could exist in solutions together with the sulfur anion. Furthermore, it should be noted that signs of oxidation-reduction reactions are indicated very poorly in a number of deposits. Many deposits are characterized by relatively large amounts of sulfides in pitchblende veins. This helps in concluding that uranium could readily go into solutions where sulfides were precipitated. In all probability this case also concerns the solution and transportation of principally tetravalent uranium. Thus a number of signs indicate that during the formation of at least some ore veins, uranium has migrated in the tetravalent state under hydrothermal conditions. In addition, it should be admittad that the up-to-date concept of the hexavalent form of uranium transport holds especially true of most deposits. (JMT)

<129>
Ragland, P.C., G.K. Billings, and J.A.S. Adams, Rice University, Houston, TX; University of North Carolina, Chapel Hill, NC

Chemical Fractionation and its Relationship to the Distribution of Thorium and Uranium in a Zoned Granite Batholith. Geochimica et Cosmochimica Acta 31:17-33. (1967)

Major element and radiometric analyses were performed on 79 samples from the Enchanted Rock Batholith, Llano Uplift, Texas. The major element data are in agreement with earlier work that the batholith is not zoned in the classical manner, from more mafic rocks along the margins to more felsic in the core, but rather in a more complex fashion. Evidence is offered to suggest that the magma fractionated before and/or during emplacement rather than after. Anomalously high uranium and thorium values can be correlated with the presence of allanite and abundant sphene, whereas the decrease in uranium content with increasing fractionation may be a result of increasingly effective oxidative processes during magmatic crystallization. Thus the distribution of thorium and uranium within the batholith is controlled by secondary, rather than primary processes. (Auth)

<130>
Richardson, K.A., Rice University, Department of Geology, Houston, TX

Thorium, Uranium, and Potassium in the Conway Granite, New Hampshire. The Natural Radiation Environment, J.A.S. Adams and W.M. Lowder (Eds.). University of Chicago Press, Chicago, IL, (pp. 39-50), 1069 pp. (1964)

The Conway granite is the most extensive and one of the youngest intrusive members of the Lower Jurassic White Mountain series in New Hampshire. An intensive study of this body has been carried out as part of research subcontracted by Oak Ridge National Laboratory to Rice University concerning the recovery of Th from common rocks. Gamma-ray Th analyses from the Conway granite, Mt. Osceola granite, and from associated syenite and prophyritic quartz syenite yielded mean concentrations of 56 ppm, 43 ppm, 23 ppm, and 38 ppm, respectively. Th is log-normally distributed in the Conway granite; thus it may be considered a low-grade Th resource containing about 3 million tons of Th per hundred feet of depth in the White Mountain Batholith. Uranium content of the granite is approximately 12-16 ppm; K is in the range of 3.5-5 percent Th and U concentrations appear to exhibit a well-defined linear relationship throughout the most of the body. Outcrop samples fall below this, suggestion U has been lost via weathering. No definite Th-U relationship was observed in one core, and this may be the result of redistribution of elements at a later basic dike intrusion (the core falls within 30 feet of the dike throughout most of its length). The same core showed a 15 percent deficiency of U 234 to U 238 in the upper 15 feet; in all other samples U 234 and U 238 were in equilibrium. The major radioactive accessory minerals indentified by x-ray diffraction were allanite, huttonite, thorite, and zircon. The range of activity of "huttonite" grains observed in the Conway granite indicates extensive isomorphism exists between huttonite and monozite. Variable alpha activity of zircon and thorite from grain to grain was also noted. The distribution of U and Th in the Conway granite, based on autoradiographic, alpha-particle, and gamma-ray spectrometric determinations, is: allanite - 7 percent Th, 2 percent U; huttonite - 28 percent Th, 12 percent U; thorite - 37 percent Th, 9 percent U; zircon - 1 percent Th, 19 percent U; dispersed or unknown phases - 9 percent Th, 59 percent U. (LKH)

<131>
Romberger, S.B., Colorado School of Mines, Department of Geology, Golden, CO

Hydrothermal Transport and Deposition of Uranium, and the Origin of Vein Uranium Deposits. Proceedings of the Joint Annual Meeting of the Geological Association of Canada, the Mineralogical Association of Canada, and the Geological Society of America, Toronto, Ontario, October 23-26, 1978. The Geological Society of America, Boulder, Colorado, (p. 480), 531 pp. (1978)

The stabilities of various aqueous uranium complexes are evaluated at up to 330 degrees C using available thermodynamic data. The distribution of aqueous uranium species are plotted as a function of pH and log oxygen fugacity to determine the complexes responsible for the transport, and the mechanisms for deposition, of uranium in natural hydrothermal systems. When these results are considered along with the hydrothermal alteration and mineral assemblages observed in vein uranium deposits, the following conclusions are reached: 1) Carbonate complexes become less important at elevated temperatures and are not significant in the transport of uranium in hydrothermal systems. 2) In deposits containing fluorine, uranyl fluoride complexes are most important in uranium transport. 3) Chloride compelxing is not significant even where chloride activities exceed 1. 4) Under certain conditions phosphate complexing may be important in transporting uranium. 5) The solubility of pitchblende decreases as temperature increases, and therefore cooling is not an adequate mechanism for deposition. 6) Uranium is deposited by an increased in pH or a decrease in activity of complexing anions. These changes may occur as a result of reaction with wall rocks, boiling and loss of volatile components, or mixing with ground waters. 7) Oxidation of iron in wall rocks may be an effect of, rather than a cause for, uranium precipitation. 8) Pitchblende can precipitate under conditions where pyrite or hematite are stable, or where iron is mobile, resulting in the bleaching of wall rocks. (Auth)

<132>
Runnels, R.T., J.A. Schleicher, and H.S. Van Nortwick, Kansas Geological Survey, Lawrence, KS

Composition of Some Uranium-Bearing Phosphate Nodules from Kansas Shales. Kansas Geological Survey Bulletin 102, Part 3, (pp. 94-100). (1953)

Detailed analyses of uranium-bearing phosphato nodules from 11 localities in eastern Kansas are reported. Seven Pennsylvanian shales were sampled. Graphs showing relationships between phosphate content and several constituents, including uranium, are presented. Combined evidence suggests that the nodules consist of collophane and dahllite with varying mixtures of impurities, primarily quartz and clay. The average composition of the 11 samples was 30.2 percent P_2O_5, 0.017 percent U_3O_8, and 3.2 percent fluorine. (Auth)

<133>
Russell, W.L., Stanolind Oil and Gas Company, Tulsa, OK

The Total Gamma Ray Activity of Sedimentary Rocks as Indicated by Geiger Counter Determinations. Geophysics 10(2):180-216. (1945, April)

Geiger counter determinations of the gamma ray intensity of 510 rock samples have been made to determine the average radioactivity and frequency distribution of radioactivities of the various types of sedimentary rocks. The results, expressed in units of gamma ray intensity, show that limestones, sandstones and dolomites are of relatively low radioactivity, shales much higher, and black bituminous shales highest of all. The new data on the gamma radiation of the sediments may be used to improve the interpretation of radioactivity logs and to determine the value of surface radioactivity surveys. (Auth)

<134>
Rydell, H.S., and E. Bonatti, University of Miami, Rosenstiel School of Marine and Atmospheric Science, Miami, FL

Uranium in Submarine Metalliferous Deposits. Geochimica et Cosmochimica Acta 37(12):2557-2565. (1973, December)

Hydrothermal submarine metalliferous deposits, common in areas of ocean floor with high heat flow, generally contain about 10 ppm uranium as an order of magnitude. The U-234/U-238 ratio is in the majority of cases close to that of seawater; only in a few cases is it anomalously high. Anomalous U-234/U-238 ratios are coupled with low U concentrations. These data are explained by a model where thermal water (essentially heated seawater) in its sub-bottom circulation often is able to leach uranium from the basaltic oceanic crust; in fact, these thermal waters may in some cases lose uranium. When leaching of uranium from the basalt does take place (probably during the shallow stages of the sub-bottom circulation) the resulting anomalous U-234/U-238 ratio can be preserved in the hydrothermal deposit only if mixing with "seawater" uranium is prevented. (Auth)

<135>
Rye, D.M., and R.F. Roy, Yale University, Department of Geology and Geophysics, New Haven, CT; Purdue University, Department of Geosciences, West Lafayette, IN

The Distribution of Thorium, Uranium, and Potassium in Archean Granites from Northeastern Minnesota. American Journal of Science 278(3):354-378. (1978, March)

The uranium, thorium, and potassium distributions in 2700 million year old granitic rocks from northern Minnesota were investigated via gamma-ray spectometry. A comparison of the Giants Range and Vermilion massif revealed that the Vermilion massif is higher in all radioelements, including potassium, within the plutonic phase than is the Giants Range. This is consistent with, but not proof of, the Vermilion and Giants Ranges having formed in a plate tectonic type regime with the Vermilion massif having formed farther from the plate boundary than the Giants Range. The highest concentrations and largest variations of thorium and uranium occur in both the Vermilion and Giants Range in rocks of the minimum melt composition. Uranium loss in the Vermilion granite apparently occurred as the result of leaching by late magmatic fluids and not as the result of weathering. Even when the rocks of a particular complex have diverse origins the Th, U, and K data seem to behave in a systematic way. The authors believe this is because thorium and uranium concentrations are low in almost all rocks formed by primary magmatic processes, regardless of potassium content. For thorium and uranium concentrations to be high the rock must have undergone a concentration process. In the case of the northeastern Minnesota rocks, the most effective concentration process was the attainment and maintenance of a granite minimum melt composition by partial melting of graywackes. The net result is that when thorium and uranium are plotted against potassium, there is a dramatic increase in thorium and uranium at the maximum potassium content of the complex. (JWT)

<136>
Sachdev, S.C., Gulf Research and Development Company, Pittsburgh, PA

Mineralogical and Geochemical Zonation Across Roll-Type Uranium Deposits - Mariano Lake Type. AAPG Bulletin 63(4):698. (1979, April)

The mineralogy and chemistry of samples from the cores obtained across Mariano orebody were determined and used to develop exploration tools for roll-type uranium deposits. Preliminary interpretations regarding the physicochemical conditions of ore deposition were made on the basis of paragenetic relations. The host sandstones are confined between the bentonitic rock units, and contain scattered intercalations of detrital montmorillonitic material in the form of clay galls, stringers, and lenses derived from these bentonites. Authigenic clay minerals identified in the host rocks include cellular montmorillonite, platy chlorite, and pseudohexagonal "books" of kaolinite. The cellular montmorillonite is concentratd in the oxidized zone and appears to have formed prior to ore deposition. Authigenic chlorite is most abundant in the ore zone and has formed at the expense of cellular montmorillonite; its formation is interpreted to be related to the ore-forming processes. Kaolinite in sandstones is the last clay mineral to form, and is enriched in the reduced zone. Calcite, considered typical of such deposits, is found to be lacking in this orebody. Iron-titanium oxides and their alteration products are the most abundant heavy-mineral species in the host rocks. In addition to anatase and rutile, the alteration products include hematite in the oxidized zone and pyrite in the ore and reduced zones. Carbonaceous material introduced later into the potential ore zone appears to have been responsible for the decomposition of Fe-Ti oxides and formation of pyrite. The oxidation of pyrite by mineralizing solutions, resulting in reduction and subsequent deposition of uranium, is indicated by the paragenetic relationship. The positive correlation between organic carbon and uranium suggests that carbonaceous material also acted as a reductant for uranium. A discriminant analysis was run using the chemical data to distinguish the geochemical zones (oxidized, ore, and reduced). Of the 15 variables used in this analysis, it was determined that the three zones could be separated using only six variables (Th, U, V, Zr, Ti, and Mn). The discriminant functions thus formulated could possibly be used to classify unknown samples in the area studied. (Auth)

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<137>
Sackett, W.M.

Geochemical Behavior of Uranium and Thorium Series Nuclides-Annual Progress Report (1974-1975). ORO-3852-20; CONF-750503-25; Fourth National Symposium on Radioecology, Proceedings of a Symposium, Corvallis, OR, May 12-14, 1975, 12 pp. (1975)

Data cited in last year's annual report indicating 50 percent more Ra 228 present in the Gulf of Mexico than found by Kaufman, et al. (1973) is being rechecked. Ra 226 has been determined on several brines samples from Gulf of Mexico oil production areas; preliminary Ra 228 values for two of them are 1813 plus or minus 87 dpm/l and 1053 plus or minus 67 dpm/l. The discharge of production brines cannot account for more than about 10 percent of the difference between 1972 and 1968 Ra 228 concentrations. It was therefore decided not to continue brine measurements in relation to a Ra budget. Freshwater inputs of Ra have been determined to be negligible, based on Texas State Department of Health surveys. Data was collected in July, 1975, on a transect across the continental shelf and into the Gulf, including samples for vertical Ra profiles. Ra 228, Ra 226, Rn 222, and CH4 values will be used to determine the magnitude and rates of advection of coastal waters into the Gulf. Other cruises are planned for October and February. A submersible pumping system has been built in conjunction with Mn-fiber/Ra sampling. This system is a significant advancement in Ra sampling. The study of Ra and U in livestock feed supplements and phosphate fertilizers has been completed. The 24 feed supplements analyzed fall into two groups: the first averages 73 percent of the equilibrium Ra 226 values, the second has Ra 226 values averaging only about 7 percent of equilibrium. From the first group, it was possible to identify three sources: PROFOS, a deflourinated phosphate manufactured by the Olin Co., and VAW-SC and VAW-PC, two mineral supplements manufactured by Vit-A-Way, Inc., using PROFOS extensively in their manufacture. PROFOS is believed to be a major parent phosphate source. Parent phosphate material for the second group of samples has not been identified; it is suggested that monocalcium and dicalcium phosphates are the parent material. The U and Ra contents in phosphate feed supplements, although high in some cases, is not a potential hazard to humans. (LKH)

<138>
Saucier, A.E.

Tertiary Oxidation in Westwater Canyon Member of Morrison Formation. AAPG Bulletin 63(4):694. (1979, April)

Hematitic oxidation in the Westwater Canyon Member of the Morrison Formation extends along the outcrop from the Pipeline fault northeast of Gallup, New Mexico, to the San Mateo fault north of Grants, New Mexico. The hematitic sandstone forms a broad lobe in the subsurface to a depth of 730 m (2,400 ft). The down-dip edge arcs eastward from northeast Church Rock through Crownpoint, and southeastward to the west edge of the Ambrosia Lake district. The red sandstone is bordered on the downdip side by a band of limonitic oxidation which interfingers with reduced sandstones basinward. The limonitic oxidation forms a relatively narrow band along the north and west sides of the hematitic lobe, but expands progressively on the east and southeast. Weak limonitic oxidation, as indicated by the absence of pyrite and a bleached to faint yellowish-gray color, appears to extend from the San Mateo fault eastward under Mount Taylor to the Rio Puerco. The hematitic oxidation is epigenetic and is believed to be of late Miocene to early Pliocene age. The limonitic oxidation follows the present groundwater flow pattern and probably dates from late Pliocene to recent. The oxidation patterns are important in uranium exploration because the hematitic area is essentially barren, whereas the limonitic areas contain ore deposits which are in the process of being destroyed by oxidation. (Auth)

Author is a consultant in Albuquerque, NM

<139>
Serebrennikov, V.S., and I.G. Maksimova, Institute of the Geology of Ore Deposits, Petrography, Mineralogy, and Geochemistry, Academy of Sciences of the USSR, Moscow, USSR

The Deposition Mechanism of Uranium from Mineral Waters Containing CO2. Geochemistry International 13(5):167-174. (1976)

The uranium distributions in carbonated waters and travertines are discussed. The uranium content in the travertine shows a direct correlation with that in the water. Fission-fragment radiography indicates that the uranium is almost uniformly distributed in the carbonates. Uranium is taken up by travertine as a result of co-precipitation with sorption on carbonates which are produced on account of the shift in the equilibrium in carbonated water consequent on gas loss. Nonstoichiometry in the carbonates can be used to demonstrate genetic relationships to carbonated water, and also as a basis for evaluating such uranium deposits. (Auth)

<140>
Serikov, Yu.S., Academy of Sciences, Institute of Petroleum and Gas Industry, Moscow, USSR

Anomalous Radioactivity of Clays. Geochemistry 5:535-539. (1963)

An investigation of the radioactivity of clays from drill holes in the Khadum Formation in the Caucasus-Crimera region showed that zones of anomalous radioactivity contained 18 to 20 ppm uranium, along with normal amounts of potassium and thorium. The unusually high concentration of uranium (six times that of normal clays) results from specific physicochemical conditions during sedimentation. The environment of deposition of the radioactive Khadum sediments was reducing and highly saline, and both organic matter and uranium accumulated under the same conditions. Uranium may have been deposited along with carbonates as calcareous clays are more radioactive than normal clays. (Auth) (JMT)

<141>

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<141>
Sharp, R.R., Jr., and P.L. Aamodt, Los Alamos Scientific Laboratory, Los Alamos, NM

Hydrogeochemical and Stream Sediment Survey of the National Uranium Resource Evaluation Project, October - December 1975. LA-6346-PR; GJBX-38(76); 85 pp. (1976, May)

The third working quarter of the Los Alamos Scientific Laboratory National Uranium Resource Evaluation (Hydrogeochemical and Stream Sediment Survey) Project has been devoted to continued planning activities, developing standardized field procedures, final testing and selection of field equipment, and procurement of sufficient materials and equipment to complete field work planned for the remainder of FY76. Analytical techniques and equipment continue to be developed, with emphasis on rapid, accurate processing using fluorimetry and automated delayed-neutron counting. Computerized data handling and evaluation systems have been developed and implemented. Field sampling in New Mexico, Colorado, and Alaska has provided several thousand water and sediment samples, and their analyses are nearing completion. (Auth)

<142>
Shilts, W.W., and C.M. Cunningham, Canada Geological Survey, Ottawa, Ontario, Canada; University of Massachusetts, Department of Geology, Amherst, MA

Anomalous Uranium Concentrations in Till North of Baker Lake, District of Keewatin. Geological Survey of Canada Paper 77-1B, Report of Activities, Part B, (pp. 291-292), 350 pp. (1977)

Samples of Pleistocene till and till-derived sediments from the vicinity of the Keewatin Ice Divide near Baker Lake, District of Keewatin, Northwest Territories, Canada, have been found to contain anomalously high concentrations of U, as well as Zn and Mo, in the less than 2μ fraction. Most of the samples are till, but those from the vicinity of Whitehills Lake and the west end of Baker Lake appear to represent marine sediments or marine-reworked till. Anomalous values are confined almost exclusively to the area east of Thelon River and north of Baker Lake. Tills in the area generally contain more Fe than those outside the area. Concentrations range as high as 130 ppm U and 24 ppm Mo. Explanations proposed for the high values are: 1) derivation from rocks intruding or forming the Archean basement (unmapped fluorite-bearing granites or syenites), 2) derivation from presently unknown U-bearing beds in the Aphebian quartzites, etc., or 3) anomalies may be caused by enhanced cation exchange capacity due to some mineralogical difference in the till (unlikely because of non-enrichment of Cu, Ni, Co, Pb, Mn, and Cd, which would be expected in such a case). The authors favor the second hypothesis; two gossans near Aphebian quartzite outcrops in the area were found to be enriched in Mo. Similar quartzites are known to be associated with U-mineralization in the Amer Lake area and elsewhere in the Amer Lake area and elsewhere in Keewatin. The pattern of anomalies may represent a complex dispersal train and possibly several sources. (LKH)

<143>
Sidorenko, G.A., All-Union Scientific Research Institute of Economic Minerals, Moscow, USSR

X-Ray Investigations of Natural Oxides of Uranium. Geochemistry 1:26-50. (1958)

It has been established that the CaF2 type structure is the only crystalline form in which uranium oxides occur in nature. As the tetravalent uranium oxide is oxidized into hexavalent uranium, the size of the elementary cell of the oxide changes. The character of dependence of the elementary oxide cell on the degree of its oxidation state is expressed by the value of the hydrogen coefficient "X". It was found that the chief reason for the diffusivity of the diffraction lines of the x-ray patterns of highly oxidized pitchblendes and sooty pitchblende is due to the high degree of their dispersivity which increases as the mineral is further naturally oxidized. The study of these transformations which the natural uranium oxides undergo in the process of their oxidation and ignition in the air has shown that their initial crystalline structure is more stable than the structure of the synthesized uranium oxides and that the course of phase transformations differs from the course of the latter. Among the ignition products of the mineral uranium oxides a new phase, named phase Y, was detected. (Auth) (JBT)

<144>
Smirnov, V.A.

Uranium and Thorium in Igneous Rocks of Western Transbaikaliya. Geochemistry 11:1115-1122. (1962)

Data on the distribution of uranium and thorium in the Lower Paleozoic and Mesozoic igneous rocks of the mobile zone of central Western Transbaikaliya are summarized in this article. In all but one of the magmatic phases and complexes investigated, uranium and thorium tend to be most abundant in the younger siliceous and alkalic differentiates. As the content of radioactive elements increases, the Th/U ratio tends to increase, although in some complexes the last differentiates contain less radioactive elements and have a lower Th/U ratio than earlier differentiates. The last differentiates are also richest in fluorite, and cause more hydrothermal alteration. It is probable that saturation of the magmas with volatile components noticeably increased the role of mobile uranium and reactivity of the magma. (JBT)

<185>
Smyslov, A.A., All-Union Geologic Research Institute, Leningrad, USSR

Radioactive Elements in Igneous Rocks of Northern Kazakhstan. Geochemistry 3:248-258. (1958)

Radioactive element concentrations were determined for intrusive and effusive igneous rocks of Northern Kazakhstan. It was found that there was a gradual increase in radioactive elements and in the Th/U ratio in the younger rocks, up to the end of the intermediate stages. In the late stage rocks, there was a decrease in the radioactive elements and in the Th/U ratio. The phenomenon or enrichment of radioelements in the roofs of intrusive bodies was noted in only one massif, and it was apparently formed in an environment of intense tectonic activity. The absence of uranium halos in host rocks, as well as the enrichment of radioactive elements in the central parts of the massifs, indicates probably a certain downward migration of uranium and possibly also of thorium during cooling of the plutonic body. Later on there was a migration of radioelements into the upper horizons, concurrent with the entry of granitoids of the second intrusive phase and of dikes. (JHT)

<186>
Somayajulu, B.L.K., and E.D. Goldberg, University of California, Department of Earth Sciences, Scripps Institution of Oceanography, La Jolla, CA

Thorium and Uranium Isotopes in Seawater and Sediments. Earth and Planetary Science Letters 1:102-106. (1966)

Thorium concentrations in three open Pacific Ocean water samples had values of n x 10(E-10) grams/liter. These concentrations were similar to those previously measured in the Atlantic. Radioactive disequilibrium exists between the dissolved forms of Th-228 and Th-232 and the dissolved, excess unsupported Th-228 is apparently introduced by the input of Ra-228 from the particulate phases containing Th-232. The Th-230/Th-232 ratios in seawater are similar to those taken from the surface sediments in the same area. Differences in Th-230/Th-232 ratios in barite and foraminifera extracted from the same levels in sediments are suggestive of differences in the ratio between surface and deep ocean waters. (Auth)(JHT)

<187>
Spalding, R.F., Texas A & M University, College Station, TX

The Contemporary Geochemistry of Uranium in the Gulf of Mexico Distributive Province. Ph.D. Thesis; 253 pp. (1972)

The Gulf of Mexico Distributive Province is composed of a sediment source area of 2,130,000 square miles, a distribution system of 99,370 miles of rivers, and a depositional area (the Gulf of Mexico) with an area of 618,000 square miles. The Gulf of Mexico receives runoff from more than half the area of Mexico and two-thirds the area of the United States, resulting in an addition of an estimated 775 million tons of detrital material and 208 million tons of dissolved solids yearly. The United States Gulf of Mexico Distributive Province has the distinction of being one of the most agriculturally advanced regions of the world. As a result, it has been speculated that the high concentration of uranium in rivers draining the agricultural regions was due to the dissolution of phosphate fertilizer. A major portion of the research described in this thesis has been devoted to ascertaining whether or not the anomalously high uranium concentrations in contemporary drainage into the Gulf of Mexico do, in fact, have such an origin. Additional investigations completed in the course of this work included the isotopic analyses of uranium in the salinity gradient of selected rivers, the seasonal analysis of soluble uranium and phosphate in the Brazos and Navasota Rivers, isotopic uranium and phosphate analyses in estuaries within apatite mining regions, a baseline study of uranium in Brazos River organisms, the assessment of rivers flowing through high uranium-bearing strata, the effects of impoundments on soluble uranium concentrations in rivers, analyses of uranium in various rock types and the investigation of uranium concentrations in phosphated detergents and feed supplements. (JHT)

<188>
Starik, I.E., L.Y. Atrashenok, and A.V. Krylov, V.G. Khlopin Radium Institute, Leningrad, USSR

Luminescent Determinations of Uranium in Rocks and Minerals. Geochemistry 8:773-776. (1956)

The presence of most elements and compounds in small concentration does not affect the uranium luminescence in NaF. This makes it possible to determine uranium quantitatively in rocks and minerals usually containing uranium not less than 10 ppm without its preliminary isolation, using the dilution of these rocks and minerals in the flux. Besides pure NaF, its mixtures with Na2B4O7, KOH, Na2CO3, K2CO3, and K2S2O7 may be used as fluxes. The admissible limit NaF ratio with these fluxes has been determined. The luminescent method without preliminary chemical treatment has been used for uranium determination in rocks (granite, limestone, coal, and clay) in the primary rock forming minerals (quartz, feldspar, calcite, muscovite, biotite, dolomite, and phosphorite) and in some accessory minerals (zircon, sphene, apatite, allanite, monazite, fluorite, garnet, rutile, wolframite, and scheelite). The dilution of the flux does not exceed 1:40 for rocks which show a minimum of determinable uranium content of 15 ppm. The required dilutions are rather different for different minerals; however, only single ones show a uranium content exceeding n x 10(E-5) g/g. This method may be of greater use with minerals with a high uranium content. (Auth) (JHT)

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<149>
Starik, I.E., and L.B. Kolyadin, V.G. Khlopin Radium Institute, Leningrad, USSR

The Occurrence of Uranium in Ocean Water. Geochemistry 3:245-256. (1957)

The adsorption on glass, cationite or anionite, the ultrafiltration and electrophoresis of hexavalent uranium in ocean water and solutions containing 2-50 x 10(E-6) and 0.1 g U/l were studied. It was found that when the content of carbonate ion in ocean water exceeds n x 10(E-6) (pH greater than 7.5, pCO2=5 x 10(E-4) atm) uranium exists in ocean water in the form of [UO2(CO3)3]-4 complex. In this state, it is incapable of passing into the bottom sediments in significant amounts. When the content of the carbonate ion in ocean water is less than n x 10(E-6)N (pH less than 7.5, pCO2=5 x 10(E-4) atm), uranium exists in ocean water in the form of the products of hydrolysis absorbed on silica-bearing colloidal particles. It is deposited on the ocean bottom at the rate determined by the rate of sedimentation of these particles. At Eh values lower than approximately 0.1 V, uranium in ocean water may be reduced to the tetravalent state and very quickly pass into bottom sediments. (JBT)

<150>
Starik, I.E., A.P. Ratner, M.A. Pasvick, and F.L. Ginzburg

Determination of Plutonium-Uranium Ratio in Pitchblende. Geochemistry 2:170-176. (1957)

Plutonium 239 was isolated from 2 kg of pitchblende. The chemical yield of the plutonium was 33.3 percent and it was shown that the ratio of plutonium 239 to uranium in the pitchblende investigated as 2.0 plus or minus 0.3 x 10(E-11). (Auth)

<151>
Sultankhodzhayev, A.N., A.I. Spiridonov, V.G. Tyminskiy, and R.S. Taneyev, Academy of Sciences, Institute of Hydrogeology and Engineering Geology, Uzbek, USSR

Nonequilibrium Uranium in Ground Waters of the Tashkent Artesian Basin. Soviet Hydrology: Selected Papers (3):285-287. (1970)

An analysis of U 234/U 238 ratios in 22 groundwater samples from the Tashkent Artesian Basin allows the basin to be divided into three zones - I infiltration zone, II transitional zone, and III deep circulation zone. Zone I occupies the feeding area and adjacent regions, has a U 234/U 238 ratio of 2-2.5 (average 2.1), an average N 2 concentration of 0.93, and is characterized by active water exchange. Zone II lies at the basin margins, has a U 234/U 238 ratio of 2.6-1.3 (average 1.9), and average N 2 value of 1.00, and is characterized by slow water flow. Zone III occupies the center of the basin, has the slowest water flow and the lowest U 234/U 328 ratios (1.3-1.8, average 1.6); average N 2 concentration is 1.02. These data show a negative correlation between U 234/U 238 and age, and positive correlations of U 234/U 238 with N 2 concentration and coefficient of water migration. (LKH)

<152>
Syromyatnikov, N.G., Academy of Sciences, Institute of Geological Sciences, Kazak, USSR

Interphase Isotopic Exchange of U 234 and U 238. Geochemistry 3:320-327. (1960)

A method of experimental investigation of interphase isotopic exchange of uranium 234 and 238 was proposed and the first data obtained. A relationship was established between the isotopic exchange and the solubility of uranium compounds of the solid phase. The isotopic exchange occurs, first, at the expense of interaction between the solution and the easily soluble part of uranium in the solid phase. The half exchange period is directly proportional to the concentration of uranium in the liquid phase and inversely proportional to the concentration of the easily soluble uranium in the solid phase. (JBT)

<153>
Szabo, B.J., USGS, Denver, CO

Uranium-Series Systematics in Natural Materials from the Newport Area, Oregon. USGS Professional Paper 800-C, (pp. C199-C201), 281 pp. (1972)

Analysis of uranium, thorium, and protactium isotopes in recent and fossil wood and kelp samples from the Newport area, Oregon, indicate that migration of these radioelements has been extensive. Because of this, such material is unsuitable uranium-series dating. The analytical data from a shell sample from the same area showed evidence of recent uranium assimilation, which contributed only to a minimum age estimate. (Auth)

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<154>
Szalay, S., and Z. Samsoni

Investigation of the Leaching of Uranium from Crushed Magmatic Rock. Geochemistry International 6(3):613-622. (1969)

Conditions of uranium leaching from crushed granite, andesite, gabbro, and basalt samples from various localities were investigated by laboratory experiments. It was observed that the uranium content of crushed granite exhibits an anomalously greater solubility than the other rocks tested. The uranium content of waters in contact with rock detritus was found to be more of an indication of the amount of leachable uranium than that of the existence of a highly concentrated, hidden uranium vein. According to the authors' results, the final equilibrium concentration of uranium in waters in contact with crushed rock is established within 3 to 5 hours. As a result of this, the examination of water samples provides information only concerning the immediate vicinity of the water within the last 3 to 5 hours. Uranium may become enriched over a longer period of time in fine-grained soils if a continuous supply of water with a high uranium content from deeper uranium rich zones occurs, in addition to adequate surface evaporation. Because of the adsorption capacity of sediments, the movement of the UO2+2 ions is hindered until the adsorption capacity is at least partially saturated. Due to the adsorption effect, the migration of the uranyl ions is significantly slower than that of the water, but after a suitably long period of time, it will appear in surface layers also. This explains the formation of aureoles with locally high uranium concentrations which may be considered an indication of the establishment of equilibrium at a larger scale. (JBT)

<155>
Szoghy, I.M., and L. Kish, Laval University, Department of Physics, Quebec, Canada; Mineral Deposits Service, Department of Natural Resources, Quebec, Canada

Determination of Radioactive Disequilibrium in Uranium-Bearing Rocks. Canadian Journal of Earth Sciences 15(1):33-44. (1978, January)

A method is presented to determine the radio-equilibrium of the uranium-actinium series in rock samples by low energy photon spectroscopy. The equilibrium pattern is indicated by the relative abundance of the isotopes U-238, Pa-231, Ra-226, Rn-222, and Pb-210. For whole rock analysis no elaborate sample preparation is needed and the measurements can be performed in the field. On chemically separated material, the uranium-234, -235, and -238 ratio can also be determined by the method. A practical table for radioactive rock analysis, listing intense photons below 250 keV energy, is also included. Measurements on uranium-bearing rocks indicate that radioactive disequilibrium is common, especially in near surface specimens. This should be taken into consideration in calculating equivalent uranium (eU) values from scintillometric measurements, and in interpreting anomalies by radon geochemistry. The deduced isotopic ratios can be used for age determination and to monitor industrial enrichment of uranium-235. (JBT)

<156>
Tanner, A.B., R.E. Moxham, and F.E. Senftle, USGS, Reston, VA

Assay for Uranium and Measurement of Disequilibrium by Means of High-Resolution Gamma-Ray Borehole Sondes. USGS Circular 753: Short Papers of the US Geological Survey Uranium-Thorium Symposium, 1977, J.A. Campbell (Ed.), (pp. 56-57), 75 pp. (1977)

In-hole assay has been done by measurement of gamma radiation since the early days of uranium exploration. Because detectors used are most sensitive to the nuclides far down the decay chain of the uranium and thorium series, radioactive disequilibrium or significant concentrations of thorium result in assay errors that can be significant. Gamma-ray detectors made of germanium are capable of resolving most of the numerous X-rays and gamma rays, and in principle, they can measure uranium directly, without regard to the state of radioactive equilibrium. Reluctance to use these high-resolution detectors in the field has resulted because they are expensive, require sophisticated electronics and data reduction, and must be cooled to liquid-nitrogen temperature for operation. High-resolution gamma-ray spectrometry is unique because it offers an in situ method of determining the state of equilibrium in the U-238 and U-235 series by simultaneous measurements using a single detector. Of the six isotopes or groups capable of independent behavior over geologically important periods of time, five can be evaluated unambiguously by at least one gamma ray; the remaining one, Ra-226, can be evaluated if a correction is made for U-235. (JBT)

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<157>
Tauson, L.V., Academy of Sciences, Institute of Geochemistry, Siberian Division

Geochemical Behavior of Rare Elements During Crystallization and Differentiation of Granitic Magmas. Geochemistry International 4:1067-1075. (1967)

In granitic rocks, there are two tendencies in the behavior of rare elements: (1) crystallochemical dispersion and (2) residual concentration. The distribution of the rare elements is determined by the size of the granitoid intrusive, its depth of formation, and composition. Intrusives may be classified as abyssal, mesabyssal, and hypabyssal with high and low volatile contents. The distribution of rare elements in abyssal batholiths is regulated primarily by crystallization differentiation, resulting in a considerable difference in the concentration of rare elements in the extreme members of the differentiated series. In mesabyssal batholiths, formed at shallow depths in a tectonically active environment, differentiation is inhibited and crystallochemical dispersion plays the dominant role in the rare element distribution. Hypabyssal intrusives with low volatile contents are weakly differentiated, and the difference in the content of rare elements in the early and late differentiates is small. Crystallochemical dispersion is the predominant factor in the distribution of the rare elements. In hypabyssal intrusives with high volatile contents and steep pressure gradients, the elements with a strong affinity for volatiles become concentrated in the late differentiates. Crystallization differentiation is inhibited in the intrusives of this type, but degassing of the deeper parts of intrusive, especially during the late magmatic and early post-magmatic stages, results in intensive migration of the rare elements. Concentration of a number of rare elements (including uranium) in the upper parts of the intrusives is characteristic, and dispersion of their contents is 15 to 20 times greater than in the hypabyssal intrusives with low content of volatiles. (JET)

<158>
Tugarinov, A.I., S.I. Zykov, and E.V. Bibikova, V.I. Vernadskii Institute of Geochemistry and Analytical Chemistry, Moscow, USSR

Determination of the Age of Sedimentary Rocks by the Lead-Uranium Method. Geochemistry 3:288-300. (1963)

Determination of the lead isotopic ratios in uranium-bearing sediments after the separation of detrital minerals allows for the dating of the time of sedimentation of sedimentary rocks by the lead-uranium method. Among the most satisfactory materials for such age determinations are uranium-bearing sulfides, apatites, and the micaceous cement of sandstones and conglomerates. Application of this method in three regions of the Soviet Union showed that the deposition of Archean strata occurred in much more ancient times and occupied a greater time interval than suggested by the K-Ar ages measured on micas and shales from the same rocks. The accumulation of the Krivoi Rog series covered a period between 2600 and 1900 million years with most of the sediments being deposited between 2300 and 1900 million years ago. (JET)

<159>
Turovskii, S.D., Academy of Sciences, Geological Institute, Kirgizia, USSR

Geochemistry of U and Th-Distribution of Radioactive Elements in Intrusive Rocks of Northern Kirgizia. Geochemistry 2:199-215. (1957)

Igneous rocks of different tectono-magmatic epochs or of the same epoch, but of magmatic stages different in age in northern Kirgizia differ substantially in their uranium and thorium contents. Intrusive rocks of Variscan tectono-magmatic epoch, as compared to similar rocks of Caledonian and even older magmatic complexes are characterized by increased uranium and thorium contents, with thorium predominanting over uranium. The character of quantitative distribution and quantitative ratios of uranium and thorium in magmatic complexes to different tectono-magmatic epochs in northern Kirgizia shows the existence of an independent protomagmatic source during each epoch, which is characterized by specific and peculiar geochemical characteristic, which later were inherited by all the derivatives separated from it during its evolutionary development. These peculiarities of uranium and thorium distribution in different magmatic complexes denote the absence of a single, general magmatic chamber. Magmatic differentiation of thorium and uranium exhibits a marked similarity in the behavior of the two elements. The maximum accumulation of both elements took place in the final petrochemical (acidic, ultra-acidic, and alkalic) differentiates. However, there are some definite principal differences in their behavior, which condition the geochemical differences between these two elements even as early as during the magmatic stage and more so during the postmagmatic processes. These differences consist in that uranium accumulates in the final differentiates in larger amounts than thorium due to its greater mobility. The empirical regularity in the uranium affinity toward potassium-rich magmas, and of thorium toward mostly sodic magmas is not always demonstrated. In definite physico-chemical conditions (mostly the amounts and composition of volatile components) thorium and uranium concentrate in essentially potassic magmas. Northern Kirgizia is a type locality in this respect. (JET)

<160>
Vine, J.D., and E.B. Tourtelot, USGS, Reston, VA

Geochemical Investigations of Some Black Shales and Associated Rocks. USGS Bulletin 1314-A; 43 pp. (1969)

The distribution of chemical elements in nine sets of samples of black shales and associated rocks were examined statistically to learn which elements accompany the major rock-forming constituents, such as detrital minerals, carbonate minerals, and organic matter. The rocks sampled range in age from Precambrian to Eocene and in environment of deposition from eugeosynclinal to carbonate lake. Equivalent uranium contents were determined in three sample sets; one each from the Sharon Springs Member of the Pierre Shale and the upper part of the Niobrara Formation, the Eagle Ford Shale and Buda Limestone, and a unnamed equivalent to the Health(?) Formation. The uranium contents ranged from less than 0.001 percent to 0.003 percent. The author believes that the more mobile elements - chromium, cobalt, copper, lead, molybdenum, nickel, silver, uranium, vanadium, yttrium, and zinc - should be given primary consideration in any search for "metal-rich" black shale deposits because their mobility may allow them to form epigenetic deposits or to be concentrated with organic matter in concentrations high enough to form ore-grade deposits. (JMS)

<161>
Vine, J.D., and E.B. Tourtelot, USGS, Denver, CO

Preliminary Geochemical and Petrographic Analysis of Lower Eocene Fluvial Sandstones in the Rocky Mountain Region. Wyoming Sandstone, R.L. Enyert (Ed.), Proceedings of the 22th Field Conference, 1970. Wyoming Geological Association, Casper, WY, (pp. 251-263), 292 pp. (1970)

A geochemical and petrographic study of lower Eocene fluvial sandstones in the Rocky Mountain region was made to determine their average composition and geochemical history. From 19 basins of deposition, 228 samples were collected according to a random sampling plan. The 228 samples range from highly arkosic sandstones derived from the Precambrian core terrain of the central Rocky Mountains to calcareous quartz sandstones derived from Paleozoic and Mesozoic thrust sheets in western Wyoming and Utah. The average major element composition is (in percent) SiO_2, 73.4; Al_2O_3, 8.0; Fe_2O_3, 1.1; FeO, 0.42; MgO, 1.3; CaO, 5.5; Na_2O, 1.1; K_2O, 1.9; H_2O, 2.1; TiO_2, 0.27; P_2O_5, 0.09; MnO, 0.07; CO_2, 4.5. Minor elements detected include (in ppm) Ba, 590; Co, 5.5; Cr, 22; Cu, 11; Ga, 11; Ni, 12; Sr, 390; V, 32; Zr, 140; Th, 7.0; U, 2.4. These values are relatively high for Al_2O_3, K_2O, CO_2, Ga, Sr, V, Ni, Pb, Co, and U, but low for Fe_2O_3, MgO, Zr, B, and La compared with several estimates of the average composition of sandstones. Nearly all samples show distinct chemical and mineralogic changes resulting from diagenetic and, locally, hydrothermal alteration. Authigenic minerals include carbonates, zeolites, montmorillonite, kaolinite, mixed-layer clays, and locally epidote and amphibole. Many samples show corrosion of quartz and silicate minerals. Hornblende was probably present in the original arkosic sediments but has since been dissolved. Alkaline carbonate solutions capable of transporting uranium were probably responsible for the alteration observed in many basins. A possible source for such waters in some basins is the connate waters expelled from the intertonguing Green River formation. (Auth)

<162>
Walker, G.W., USGS, Washington, DC

Age of Uranium-Bearing Veins in the Conterminous United States. USGS Professional Paper 455-B, (pp. 29-35). (1963)

Isotopic age determinations as well as geological interpretations related to age of host rocks and confining structures indicate that the dominant age of uranium mineralization in veins in the conterminous United States is Late Cretaceous or Tertiary. Deposits of this age are widely distributed throughout the western United States and include virtually all the veins from which significant amounts of uranium ore have been produced or which contain large ore reserves. Other periods of uranium mineralization in veins in the conterminous United States are Precambrian, Paleozoic, and possibly Mesozoic in age. Dominant periods of uranium mineralization in other parts of the world seem to be mainly Precambrian or Paleozoic in age. (Auth)

<163>
Weaver, P., Gulf Oil Corporation, Houston, TX

A Theory of the Distribution of Radioactivity in Marine Sedimentary Rocks. Geophysics 7(2):192-199. (1942, April)

Gamma-ray measurements of marine sedimentary rocks indicate that in general the slower the rate of deposition the greater the radioactivity. The most recent measurements of the radioactivity of sea water suggest an increase with depth, which indicates a very slow settling of small particles. It is believed that a geologic time-scale of sedimentation can be established, subjects to certain corrections due to fixation of radioactive minerals by organisms. (Auth)

GEOCHEMISTRY

<164>
Yermolayev, N.P., A.P. Zhidikova, and V.A. Zarinskiy, V.I. Vernadskii Institute of Geochemistry and Analytical Chemistry, Moscow, USSR

Transport of Uranium in Aqueous Solutions in the Form of Complex Silicate Ions. Geochemistry 2(4):629-641. (1965)

Under certain conditions uranium may be transported in nature in the form of an aqueous solution of a hydroxy-uranyl-silicate complex of the (UO2OH)(HSiO3) type. The hydrosilicate ion may be considered either as a group stabilizing the hydroxyuranyl ion in solution or as a ligand of a weak complex. The particle size of this complex is intermediate between that characteristic of ionic solutions and of colloidal suspensions. Uranium migrates in this form in nearly neutral or weakly alkaline solutions, at temperatures up to 200 degrees C, if the concentration of strong electrolytes in the solution is relatively low (not higher than their equilibrium concentration with the uranyl and silicate ions). In carbonate solutions the uranyl silicate complex is decomposed and the uranyl ion forms a carbonate complex. (JBT)

<165>
Yershov, V.M., Academy of Sciences, Institute of Geophysics, Ural Scientific Center, Sverdlovsk, USSR

A Method of Examining the Diffusion Parameters of Lead in Uranium Minerals. Geochemistry International 11(5):1099-1101. (1974)

A distillation method is used to determine the diffusion parameters of lead in uranium minerals. Lead distillation isotherms for uraninites indicate that lead occurs in two different positions: disordered and stable domains, which should be taken into account in calculating the diffusion coefficient. (Auth)

<166>
Yes'kova, E.M., D.A. Mineyev, and I.G. Mineyeva, Academy of Sciences, Institute of Mineralogy, Geochemistry, and Crystal Chemistry of Rare Elements, Moscow, USSR

Uranium and Thorium in Alkalic Rocks of the Urals. Geochemistry 9:885-894. (1962)

The average thorium content in nepheline syenites of most of the alkalic massifs studied was similar to its content in igneous rocks in general. Unlike thorium, however, uranium is strongly concentrated in these rocks and its average content is higher than that of granites. Typically, the thorium content in alkalic rocks is higher than the uranium content, but in the miaskites of the Borsuk-Sai massif this relation is reversed. The variations in the Th/U ratio in alkalic rocks are caused mainly by variations in the uranium content with the thorium content remaining fairly constant. A direct correlation of the total uranium and thorium contents was found with the content of rare earth elements. A less direct correlation was found between the sum of uranium and thorium contents and the niobium and zirconium contents. (JBT)

<167>
Yevseyeva, L.S., and N.P. Fomina

Oxidation-Reduction Properties of Sedimentary Uranium-Bearing Rocks. Geochemistry 11:1093-1098. (1963)

The oxidation-reduction (Eh) properties of sedimentary rocks are among the most important geochemical factors responsible for the precipitation and concentration of uranium from ground waters. Investigation of the oxidation-reduction properties of rocks as a part of complex hydrogeochemical investigation broadens the possibility of evaluating sedimentary rocks as carriers of uranium. The Eh of a series of samples from a uraniferous sandstone-shale formation and a uraniferous carbonaceous-carbonate formation was measured by the K2Cr2O7-H2SO4 method or by a modification of this method using KMnO4-KOH solutions. The uranium and pyrite contents were found to be directly proportional to the change of Eh. The greatest change in Eh took place in rocks that contained organic matter. The uranium content is low despite a large change in Eh if the permeability of the rock is low. This fact confirms the uranium is epigenetic. (JBT)

<168>
Zentilli, M., W.S. Mitchell, K.A. Taylor, and P.F. Taylor, Canada Geological Survey, Ottawa, Ontario, Canada; Dalhousie University, Department of Geology, Halifax, Nova Scotia, Canada

Studies of Distribution of Uranium in Selected Ore Environments Using Nuclear Track Techniques. Geological Survey of Canada Paper 77-1B, Report of Activities, Part B, (pp. 181-183), 350 pp. (1977)

> Over 350 bulk analyses for U were carried out on mineral separates, whole-rock, and ore samples from a variety of ore environments in Canada. Polished thin sections of several rocks and ores were prepared for U-track mapping. Preliminary results are reported. Analyses of fluorites from St. Lawrence, Newfoundland found the highest U concentrations (5.76 ppm) in white, milky fluorites at a vein wall in contact with granite containing 7.8 ppm U. At Gays River, Nova Scotia, fluorites with 2.59 ppm U were obtained. No correlation between U concentration and purple color or hydrocarbon association was observed. Possible positive correlations of U content with crystallization temperature will be investigated using fluid inclusions. Analyses of massive sulfide and barite deposits found 3-10 ppm U in ore specimens from the Maclean orebody, Buchans, Newfoundland, although galena or barite ores are generally much lower (0.00-0.09 ppm). Associated volcanics ranged from 0.09 ppm U (amygdular andesitic basalt) to 2.6 ppm U (dacite rhyolite). Specimens from the Ming deposit, Rambler Mine, Newfoundland, had up to 4.5 ppm U; the schistose metavolcanic host was only 0.5 ppm U. Barites from Magnet Cove, Nova Scotia, range as follows: massive white barite - 0.03 ppm U; yellow-strained barite with hydrocarbon-rich nodules - 0.36 ppm U; barite with erythrite - 2.17 ppm U; massive orange barite - 13.57 ppm U (U concentrated in small, unidentified inclusions). Specimens of banded sulphides from the site contained 1-2.6 ppm U. The Pb/Zn deposits of Pine Point and Polaris Mine, Northwest Territories, Newfoundland Zinc, Daniel's Harbour, Newfoundland, and Gays River, Nova Scotia yielded values of 0.002 0.012 pp U for galena, 0.006-0.068 ppm U for sphalerite, 0.775-1.068 ppm U for marcasite, and 0.011-0.472 ppm U for associated calcite and dolomite (2.438 - 3.435 ppm at the Polaris Mine); the host carbonates contain 0.9-2.3 ppm U. These results are being evaluated in relation to geochemical and genetic considerations for Mississippi Valley-type deposits. U content in a suite of 16 samples from a felsic porphyritic pluton associated with Mo mineralization at Deep Cove, Nova Scotia, varies from 0.65 to 6.07 ppm U (average 2.76). Highest values are in the groundmass of coarse porphyritic phases and in mineralized zones with phyllic alteration; values are lower in phases rich in hydrothermal biotite, K-feldspar, quartz, and molybdenite. (LKH)

<169>
Zhil'tsova, I.G., L.N. Karpova, G.A. Sidorenko, and A.A. Valuyeva

Formation of Metastable and Stable Modifications of Iriginite by the Action of Uranium-Bearing Solutions of Powellite. Geochemistry International 7(4):688-692. (1970)

> Acid (pH 3.15-3.75) solutions of uranyl nitrate containing 0.1-1.0 percent uranium act on synthetic powellite ($CaMoO_4$) under normal conditions to produce a metastable modification of iriginite $UO_2(HMoO_4)_2 \times 3H_2O$, whose deposition requires a considerable excess of uranium over molybdenum in the solution. This metastable form has properties intermediate between those of iriginite and calcium uranium molybdate. Nitrate solutions containing over 3 percent uranium act on synthetic powellite under normal conditions to replace the powellite spherulites by clumps of grains with a cryptocrystalline structure. The new phase is stable iriginite, which closely resembles the natural material. (Auth) (JMT)

<170>
Zhukova, A.S., Academy of Sciences, Institute of Geochemistry and Mineral Physics, Kiev, USSR

Uranium Contents of Precambrian Formations in the Ukrainian Shield. Geochemistry International 10(7-8):930-938. (1974, July)

> The uranium contents of igneous, sedimentary, and metamorphic rocks from different tectonic settings in the Ukrainian Shield are presented. The mean uranium content for these rocks was calculated to be 4.1 ppm. The magmatic and ultrametamorphic formations on the whole have higher uranium contents (4.4 ppm) than the sedimentary and volcanic formations (3.1). The mean uranium content for the shield as a whole is higher than that for the Earth's crust. This is attributed to formations dating from the late orogenic and postorogenic periods of the geosynclinal and the platform stages which are enriched in uranium. (JMT)

GEOCHEMISTRY

<171>
Zhukova, A.M., I.A. Bergman, and G.V. Zhukov, Academy of Sciences, Institute of Geochemistry and Mineral Physics, Kiev, USSR; V.I. Vernadskii Institute of Geochemistry and Analytical Chemistry, Moscow, USSR

Distribution of Uranium in the Geological Formations of the Ukrainian Shield. Geochemistry International 12(3):103-116. (1975)

The uranium content of igneous, metasedimentary, and metavolcanic formations of the Ukrainian Shield was determined by luminescence and radiochemical methods. There was little variation in the uranium content in the volcanic formations and in most cases it does not exceed 5 ppm. The lowest uranium contents were characteristic of formations related to mafic volcanism of the geosynclinal stage. The uranium content in the metamorphosed volcanic rocks depended on the composition of the primary rocks, and increased from mafic to felsic volcanics. In the sedimentary formations, the lowest uranium concentrations were found in the ferruginous siliceous rocks. In the iron-rich zones, the uranium content ranged between 1 and 1.3 ppm, but in the schists often reached 4 to 4.6 ppm. The distribution of uranium in the sedimentary iron deposits was determined by differences in the facies and composition of the initial sediments. Somewhat higher uranium contents characterized the lower terrigenous formations of the orogenic stage of development. In the lower formation of the Krivoy Rog series the average uranium content was 12.5 ppm and increased regularly downward in the section. The increase was partially dependent on the grain size of the clastic rocks, i.e., increasing from 5.2 ppm in phyllites to 15.6 ppm in the coarse-grained basal rocks. The enrichment of the coarse-grained rocks in uranium is believed to be related to the presence of organic matter. The content of uranium in the sedimentary and sedimentary-volcanic formations was controlled by several factors. Sometimes the content was due to the presence of felsic volcanics, sometimes to the presence of organic matter, accessory minerals, or the structural position of the formation. (JMT)

<172>
Zhuravlev, R.S., and D.K. Osipov, Academy of Sciences, Institute of Geology and Geophysics, Siberian Division, Novosibirsk, USSR

Uranium in Mafic Rocks of the Patyn and Bol'Shaya Kul'Tayga Massifs of Gornaya Shoriya. Geochemist. v 2(2):308-312. (1965)

The average uranium content in the mafic rocks of the Patyn and Kul'-Tayga regions of Gornaya Shoriya is 0.43 ppm. In the process of emplacement of the mafic massifs, the concentrations of uranium decreased up to the stage of formation of alkalic and silicic. During the crystallization of the alkalic and silicic rocks, there was a gradual increase in uranium content, and a maximum was reached during the formation of the dikes. There is no direct correlation between the contents of potassium and uranium in the rocks. During the early stages of emplacement of the Patyn gabbros, the content of potassium remained constant but the content of uranium decreased, while in the later stages the content of uranium increased but the content of potassium decreased until the complete disappearance of its only carrier, biotite. The principal carrier of uranium in the mafic rocks was plagioclase, which generally contains most of the uranium present in the rock. In granite massifs, the earlier rocks contain less uranium than the later, but in gabbro massifs, the earlier rocks are richer in uranium than the later. In both cases, plagioclase becomes gradually enriched in uranium. The mafic intrusive rocks were not Palingenetic and did not obtain uranium from the pre-existing rocks except by mechanical assimilation. Increase in the concentration of uranium in the enclosing rocks near the contact depended on the degree of metamorphism. The strongest enrichment occurred during the regressive hydrothermal metamorphism. (JMT)

<173>
Zhuravleva, L.N., L.A. Berezina, and Ye.M. Gulin

Geochemistry of Rarer and Radioactive Elements in Apatite-Magnetite Ores in Alkali-Ultrabasic Complexes. Geochemistry International 13(5):147-166. (1976)

Apatite-magnetite ores have the specific element association characteristic of the accompanying carbonatites (Ta, Nb, U, Th, Zr, Ti); hatchettolite, pyrochlore, zirkelite, and baddeleyite are the main concentrators of the rare and radioactive elements, since they contain 86-96 ppercent of the total amount in the rock. The rare and radioactive elements behave similarly during the formation of alkali ultrabasic complexes containing carbonatites and also ones containing apatite-magnetite ores. The latter are syncarbonatite deposits. There are close correlations between the rare and radioactive elements in tantalum-bearing apatite-magnetite ores containing calcite and also in the carbonatites, which means that gamma spectrometry can be used to map ore bodies and make rapid measurements of niobium and tantalum contents of bedrocks, samples, and dressing products. (Auth)

<174>
Zielinski, R.A., USGS, Denver, CO

Uranium Abundances and Distribution in Associated Glassy and Crystalline Rhyolites of the Western United States. Geological Society of America Bulletin 89(3):409-414. (1978, March)

The abundance and distribution of uranium in 11 units of rhyolitic lava and ash-flow tuff of calc-alkaline and trasitional composition were analyzed. All samples came from the western United States. The study was initiated in order to evaluate the potential of rhyolitic glass as a source of uranium ores. The samples consisted of obsidians, perlites, and felsites that ranged in age from Pleistocene to Oligocene. Uranium concentrations in the obsidians ranged from 5 to 46 ppm, with the coexisting perlites having identical (plus or minus 5 percent) uranium contents. This fact indicates that little or no uranium is lost during the hydration of these glases. Felsites, however, show uranium depletion as high as 80 percent relative to coexisting obsidians and perlites. Combination of this data with the results of earlier work on peralkaline rhyolites indicates that uranium depletion seems to increase with age, with different rates of depletion from calc-alkaline (slowest) to peralkaline (fastest) compositions. Uranium distribution is inhomogenous in felsites. Electron microprobe analyses of the least-depleted felsites indicate that uranium is associated with concentrations of Fe-Ti-Mn oxides or is in accompanying accessory minerals. Secondary Fe-Mn oxides in older, depleted felsites are uranium-bearing, especially along fractures or flow layers. Uranium loss from felsites seems to be largely controlled by low-temperature solution over long periods, with some precipitation in secondary phases. (Auth) (JMT)

<175>
Zielinski, R.A., K.R. Ludwig, and D.A. Lindsey, USGS, Denver, CO

Uranium-Lead Apparent Ages of Uraniferous Secondary Silica as a Guide for Describing Uranium Mobility. USGS Circular 753; Short Papers of the US Geological Survey Uranium-Thorium Symposium, 1977, J.A. Campbell (Ed.), (pp. 39-40), 75 pp. (1977)

Case studies of the Shirley Basin in Wyoming and the Thomas Range in Utah were presented to illustrate the use of U-Pb isotope systematics to investigate the timing of migration of uraniferous silica saturated solutions. The investigation was based upon the assumption that the time of uranium mobilization is reflected in the U-Pb apparent ages of secondarily precipitated, uraniferous, cryptocrystalline silica. Apparent ages of secondary silica can be compared with ages of host rocks and nearby uranium deposits to further describe the timing of uranium migration in a particular area. (JMT)

<176>
State of Alaska, Department of Natural Resources, Division of Geological Survey, College, AK

Uranium Prospecting in Alaska. Alaska Geological Survey Information Circular 4; 5 pp. (1968, March 7)

During the 1950's, a considerable amount of exploration was done by the AEC and by private prospectors in Alaska. The work was aimed almost entirely at discovering hydrothermal deposits in the old highland areas. The Ross-Adams deposit, which was discovered near Ketchikan by prospectors, was the only mine found as a result of this effort. The AEC work consisted of testing old prospects for radioactivity and of sampling of concentrates from stream sediments and placer deposits below areas likely to contain ore deposits. The results indicated that Southeastern Alaska and the Seward Peninsula are the most favorable regions for prospecting for vein-type deposits. Strata-bound uranium deposits found in relatively flat-lying deposits in porous permeable sedimentary rocks are the most productive source of uranium. Such deposits are most likely to occur "down stream" from exposures of acid intrusive or extrusive rocks (granites or rhyolites). In Alaska, such areas are most likely to be found in the Cenozoic basins which form great lowlands and possibly on the Arctic Slope. Deposits would likely be found where acid igneous rocks are present over large areas of the surrounding hills (e.g. Western Copper River basin, Eastern Susitna River valley, and Bristol Bay area). The likely host rocks would be sandstone or conglomerate of Tertiary or possibly of Quaternary age and the deposits would be expected to occur within a few tens to hundreds of feet from the surface. Locally, the higher beds in the great Cretaceous conglomerate basins are non-marine and younger than nearby granites. Some of these beds may have been favorably situated at some time in their history to act as host rock for uranium deposits. The abundance of granitic intrusive rocks in Southeastern Alaska, the Interior, and elsewhere in the state suggests that prospecting of such areas for hydrothermal type deposits has a reasonable chance of success. Direct sensing of gamma rays is one of the principal means of detecting uranium deposits, but their limited range and penetration power through a thin cover of rock or water seriously limits the effectiveness of radiometric surveying from air or ground. Stream sediment and soil sampling offers a means of detecting uranium deposits which might be missed by aerial radiometric surveying. Analyses of the sediment samples would be sensitive down to a few ppm uranium to detect all anomalies. (JHT)

<177>
International Atomic Energy Agency, Vienna, Austria

Radiometric Reporting Methods and Calibration in Uranium Exploration. IAEA Technical Reports Series No. 174; 57 pp. (1976)

The radiometric methods and calibration utilized in uranium exploration are reviewed in this report, and the following recommendations are made in order to standardize these methods: (1) A standardized system of reporting all radiometric measurements, and a standardized method of calibrating instruments used to make such measurements are essential in order to increase the comparability and consistency of radiometric surveys and establish a simple basis of judging the significance of the resuls. (2) All reports of radiometric measurements should contain an adequate description of the methods and instrumentation used. (3) All measurements of total radioactivity should be reported in terms of a new unit, to be known as a unit of radioelement concentration, abbrevition ur, which is defined in terms of the instrument response to one part per million uranium in equilibrium. (4) Where circumstances justify the use of total count measurements to indicate the abundance of a specific radioelement, the abundance will be expressed in terms of potassium, equivalent uranium (eU), equivalent thorium (eTh), in either per cent or parts per million as appropriate. (5) All measurements made by gamma-ray spectrometry should be reported in terms of dry weight radioelement abundance, thus percent potassium (percent K), parts per million equivalent uranium (ppm eU), parts per million equivalent thorium (ppm eTh). (6) The correlation between count rate and concentration and any relevant correction factors for each instrument should be determined by the use of standard calibration sources of compositions and dimensions outlined in this paper, and fully reported. (JHT)

<178>
Lawrence Livermore Laboratory, Livermore, CA

Hydrogeochemical and Stream-Sediment Reconnaissance Survey of the National Uranium Resource Evaluation (NURE) Program - Western United States: Quarterly Progress Report, October through December 1977. GJBX-71(78); 14 pp. (1978, April 1)

During the quarter, October-December 1977, weather and the death of a contractor stopped four field projects that were in progress. Revisits to these areas are planned for the spring. A 6500 square kilometer (2500 square mile) reconnaissance project in southern Nevada was completed and site selection and planning for three projects that will cover 168,000 square kilometers (65,000 square miles) in Nevada and Arizona in the spring and summer of 1978 was finished. Ground water programs in Nevada, Arizona, and Washington are continuing on schedule. Orientation sampling in Idaho and Arizona was completed, and plans for a southern California study early next quarter were finalized. Sediment processing contractors performed acceptably. Neutron activation analysis of routine samples began and nearly 1200 samples were analyzed. Final raw-data reports for two orientation studies in Nevada were prepared and work began on three others. Computer codes were written to provide interactive generation of multiparameter correlation plots and tables. (Auth) (JHT)

<179>
Lawrence Livermore Laboratory, Livermore, CA

Hydrogeochemical and Stream-Sediment Reconnaissance (HSSR) Survey of the National Uranium Resource Evaluation (NURE) Program - Western United States: Quarterly Progress Report, July through September 1977. GJBX-45(78):13 pp. (1978, January 20)

During the quarter, July-September, 1977, reconnaissance sampling projects in Washington, Idaho, and Nevada covering 130,000 square kilometers were initiated. In addition, Bendix Field Engineering Corporation personnel collected sediment and surface water samples from major portions of the three project area; covering 175,000 square kilometers in the aforementioned states and Arizona. Orientation studies in east-central Idaho (Idaho Basins) were also initiated and the third and final phase of the Arizona orientation study in the Sierra Ancha region was completed. Groundwater sampling in the Great Basin by Desert Research Institute (DRI) continued on schedule, and new groundwater sampling contracts were placed with Washington State University and the University of Arizona. Full-scale operation of the sample analysis systems were delayed until the next quarter by a number of unexpected hardware reliability problems. Computer codes and equipment became available for preparing the hard copy data tables, microfiche, statistical summary plots, and map overlays required for reporting. (Auth)(JMT)

<180>
Nuclear Techniques for Mineral Exploration and Exploitation. CONF-691229; Proceedings of a Panel, Krakow, Poland, December 8-12, 1969. International Atomic Energy Agency, Vienna, 187 pp. (1971)

Nuclear techniques, which have become accepted for routine use in the oil industry and in uranium prospecting, are gaining wider recognition for applications in the exploration for and expliotation of the more conventional mineral resources. The International Atomic Energy Agency convened a Panel in Krakow, Poland, from December 8 to 12, 1969 on Nuclear Techniques and Mineral Resources in the Developing Countries to review the present status and to identify those techniques most suitable for adoption by developing countries. A summary of the finds of this Panel is presented in this proceedings, together with individual contributions prepared from the working papers presented by the panel members. (JMT)

Five of the fifteen papers presented in this panel proceedings have been abstracted and are listed separately.

<181>
Oak Ridge Gaseous Diffusion Plant, Oak Ridge, TN

Hydrogeochemical and Stream Sediment Reconnaissance Basic Data for Enid NTMS Quadrangle, Oklahoma. GJBX-7(79); K/UR-110; 138 pp. (1978, December 8)

Groundwater data indicate that the most promising area for potential uranium miineralization occurs in the western part of the quadrangle. Rocks in this area belong to the Permian Garber Sandstone and Hennessey Group. Many areas of high-uranium concentration also occur in the west-central part of the quadrangle in rocks of the Permian age Wellington Formation. The associated elements indicate that anomalous uranium in groundwater is probably derived from continental sandstone facies. Stream sediment data show high-uranium values occurring primarily in the north central area of the quadrangle. Rocks cropping out in this area belong to the Pennsylvanian Ada Group through the Permian Garber Sandstone, but high-uranium concentrations do not appear to be limited to any one geologic unit. The associated elements indicate that anomalous uranium may be derived from phosphatic rocks and from heavy and resistate minerals. (Auth)(PAG)

Field and laboratory data for 677 groundwater and 516 stream sediment samples are presented in the appendices.

<182>
Oak Ridge Gaseous Diffusion Plant, Oak Ridge, TN

Hydrogeochemical and Stream Sediment Reconnaissance Basic Data for Ardmore NTMS Quadrangle, Oklahoma. GJBX-142(78); K/UR-111; 38 pp. (1978, October 20)

Results of a reconnaissance geochemical survey of the Ardmore Quadrangle, Oklahoma are reported. Field and laboratory data are presented for 745 groundwater samples and 782 stream sediment samples. Statistical and areal distributions of uranium and possible 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. Groundwater data indicate that the most promising areas for potential uranium mineralization occur in the western half of the quadrangle. Geologic units in this area include the Oscar Group of Pennsylvanian age, the Hennessey and El Reno Groups, Garber Sandstone, and Wellington Formations of Permian Age. Several high values of uranium occur in groundwater near known asphaltite deposits in the folded Paleozoic rocks of the Arbuckle Mountains. Stream sediment data indicate that high values of uranium are associated with the folded and faulted Paleozoic rocks in the Arbuckle Mountains, the Pennsylvanian-Permian rocks in the western third of the quadrangle, and the Lower Cretaceous rocks in the southeastern part of the quadrangle. Most of the high-uranium values occurring in these rocks appear to be associated with heavy and resistate minerals. (Auth)

Three appendicies are included giving data on the water analyses, stream sediment analyses, and computer codes used for the data.

<183>
Allman, N.J.

Exploration on the Increase at Last. The Northern Miner 64(52):A1, A15-A19. (1979, March 8)

Expenditures for uranium exploration in Canada in 1979 is projected to increase considerably over the past year. Much of the exploration is in Saskatchewan. In 1978, over 70 million dollars was spent by 120 companies in Saskatchewan, and it is expected that over 80 million dollars will be spent in 1979. At the end of 1978, 29,769,216 acres were held under disposition, 18,486,585 acres of which had been acquired during the year. The increase reflects the influence of the conclusions of the Bayda commission and the greater interest in the deeper parts of the Athabasca sandstone basin. Active uranium exploration is also going on in the Northwest Territories, particularly west of Coppermine, and west of Baker Lake. Exploration in Manitoba is increasing due to recent changes in the mineral regulations and royalty and tax acts. In Ontario, exploration is still much less than in years past, but an increase in claim staking did occur in 1978. Active uranium exploration is going on south of Lake Nipigon and in the Timmins district. A uranium discovery on Consolidated Durham Mines and Resources antimony mine property in southern New Brunswick has resulted in increased interest in that province and uranium exploration in Nova Scotia has been stimulated by a discovery near Deer Lake. (JET)

<184>
Arendt, J.W., Oak Ridge Gaseous Diffusion Plant, Oak Ridge, TN

Hydrogeochemical and Stream Sediment Reconnaissance Program in Central United States: Semiannual Progress Report, April 1 Through September 30, 1978. K/UR-21, Part 1; 13 pp. (1978, October 6)

Union Carbide Corporation, Nuclear Division, under contract with the U.S. Department of Energy, is continuing to conduct its survey of 154 National Topographic Series 1 degree by 2 degree quadrangles which cover approximately 2,500,000 square kilometers (1,000,000 square miles) of the Central United States. A progress report on quadrangle sampling, analyses, and reporting by the Uranium Resource Evaluation Project is presented in this report. (Auth) (JET)

<185>
Baltz, E.H., Jr., USGS, Washington, DC

A Reconnaissance for Uranium in Parts of New Mexico and Colorado, 1954. TEM-929; 44 pp. (1955, June)

Reconnaissance investigations for uranium in parts of New Mexico and Colorado were undertaken in 1954 with portable Geiger counters, scintillators and carborne scintillation equipment. Samples of copper-bearing arkosic sandstone of the Cutler Formation collected in the northwestern part of Jemez Plateau, Rio Arriba County, New Mexico, contained 0.002-0.10 percent uranium. The Bandelier Tuff of Pleistocene age contains traces of radioactive material throughout much of this region. Samples of intrusive and extensive igneous rocks of Tertiary and Quaternary ages from the Chico Hills, eastern Colfax County, New Mexico contained 0.0016-0.0024 percent uranium. Radioactivity was detected in igneous rocks of intermediate composition at all localities examined, but no radioactivity was detected in basic igneous rocks or in sedimentary rocks which enclose the intrusives. Precambrian, Pennsylvanian, Permian, and Tertiary rocks were examined in the Sangre de Cristo Mountains in northern New Mexico. A sample of limonite from a fracture in Precambrian metamorphic and igneous rocks in Gallinas Canyon, San Miguel County, contained 0.022 percent uranium. Samples of carbonaceous sandstone and conglomerate of the Chinle Formation of Triassic age collected south of the Canadian Escarpment, San Miguel County, New Mexico, contained 0.004-0.070 percent uranium. Several prospects near the town of Sabinoso contained uranium deposits of possible economic value. The extent of these deposits has not been determined. No significant radioactivity was detected in Permian, Cretaceous, and Quaternary sedimentary rocks and Tertiary intrusive rocks examined at places in Lincoln and Otero Counties, New Mexico. Radioactivity estimated to be 0.008 percent equivalent uranium was detected in limestone of the Wanakah Formation of Jurassic age near Cuchara Camps, Huerfano County, Colorado. A sample of acidic tuff of the Devil's Hole Formation of Miocene age collected in northern Huerfano County contained 0.0011 percent uranium. (Auth)

<186>
Barthel, F., Bundesanstalt fur Geowissenschaften und Rohstoffe, Hannover, Federal Republic of Germany

Methods of Prospecting for Uranium Ore Deposits. Kerntechnik Atompraxis 18(10):421-426. (1976)

A brief review of the forms of concentration of uranium in the earth's crust is followed by a discussion of the most important prospecting methods. In radiometric prospecting the separate recording of the radiation from uranium, thorium and potassium (spectrometry) is of the greatest value in addition to determining the total radiation. The track etch method uses measuring capsules to determine the concentration of radon gas in the soil air. Borehole logging indicates the thickness and depth of mineralized horizons. Radioactivity, electric resistance and conductivity are generally measured. In geochemical prospecting the distribution of uranium in water, soil and river sediments is used to delineate uranium bearing areas. (Auth)

<187>
Bivens, H.M., D.H. Jensen, W.B. Ralston, and W.A. Stephenson, Sandia Laboratories, Albuquerque, NM

Direct Measurement of Uranium by Prompt Fission Neutron Method of Pulsed Neutron Borehole Logging. AAPG Bulletin 63(4):686. (1979, April)

The capability provided by neutron logging techniques for the direct measurement of uranium is extremely valuable, especially in low-grade uranium mineralization not in equilibrium. Sandia Laboratories is developing one of these techniques which is based on the detection of epithermal prompt fission neutrons that result from the irradiation of uranium by 14 MeV neutrons from a pulsed neutron generator. A 70-mm O.D. development-model logging probe has been used in a limited field evaluation of the prompt fission neutron method of logging. From this evaluation has evolved a prototype logging probe and the basis for log interpretation. Additional logs required for interpretation are a caliper log and a density log. Additional probe development is under way including a neutron generator with a neutron output greater than 10 (E+9) n/s. A vendor is being developed as a commercial source for the neutron generator. A definition of the interim logging system has been released and the system eventually developed will be defined in the open literature. (Auth)

<188>
Bolivar, S.L., Los Alamos Scientific Laboratory, Los Alamos, NM

Uranium Hydrogeochemical and Stream Sediment Reconnaissance of the Aztec NTMS Quadrangle, New Mexico. GJBX-129(78); LA-7238-MS; 75 pp. (1978, October)

A total of 338 water and 1744 sediment samples were collected from 1876 locations in the Aztec quadrangle, New Mexico. Water samples were collected from wells, springs, streams and artificial ponds. Sediment samples were collected from springs, streams, and artificial ponds. The uranium concentrations in waters ranged from below the detection limit of 0.2 ppb to 67.3 ppb. The mean uranium concentration for all water types if 2.68 ppb. Because of the lack of available surface waters and the uneven distribution of wells, interpretation of water data was difficult. Only one small cluster of three water samples containing anomalous uranium concentrations is noted. These samples, collected about 50 km north of Cuba, were taken from drainages that cut the San Jose formation. Several individual water samples with anomalous uranium concentrations are associated with fault zones. Sediments collected in this study had uranium concentrations that ranged between 0.3 ppm and 30 ppm, with a mean concentrations of 4.23 ppm. The majority of anomalous sediment samples were collected from areas underlain by either the Nacimiento or San Jose formation in the San Juan basin. Just northwest of Cuba a small cluster of sediment samples with anomalous uranium concentrations occurs surrounded by several known uranium deposits. (Auth) (PAG)

Appendix A - Summary of Standard Field and Analytical Procedures, Appendix B - Listings of Data for Water Samples, Appendix C - Listings of Data for Sediment Samples, Appendix D - Code to Data Listings

<189>
Bolivar, S.L., Los Alamos Scientific Laboratory, Los Alamos, NM

Uranium Hydrogeochemical and Stream Sediment Reconnaissance of the Bozeman NTMS Quadrangle, Montana. GJBX-8(79); LA-7504-MS; 98 pp. (1978, November)

A total of 1251 water and 1536 sediment samples were collected from 1586 locations over a 17,400 sq km area at a nominal density of one location per 10 sq km. Samples were collected predominantly from surface streams although 38 ground water locations were also sampled. The uranium concentrations in waters sampled range from below the detection limit of 0.20 ppb to 41.35 ppb. The mean uranium concentration for all water types is 1.17 ppb. Waters with anomalous uranium concentrations were found in tributaries of the Boulder River which drain Precambrian rocks in the Beartooth Mountains and in tributaries of the Three Forks basin which are underlain predominantly by Tertiary-Quaternary sediments. The two areas appearing most favorable for future exploration on the basis of water data are in the Three Forks basin in the vicinity of the Madison plateau and in a district about 20 km due west of Three Forks. Sediment samples from the quadrangle were found to have uranium concentrations that range from 0.90 ppm to 94.30 ppm, with a mean concentration of 3.71 ppm. The majority of anomalous sediment samples were collected from areas underlain by Precambrian rocks. Based on the data from sediments, the areas appearing most favorable for future exploration include the tributaries of the Boulder River in the Beartooth Mountains, the northern part of the Madison Range, and the Tobacco Root Mountains just north of Virginia City. The uranium concentrations in the sediments from these areas are probably associated with uraniferous siliceous veins or pegmatites. (Auth) (PAG)

Appendix A-Summary of Standard 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-Cumulative Frequency Plots of Uranium Concentrations in All Waters, Spring Waters, and Stream Waters, Appendix -Cumulative Frequency Plot of Uranium Concentrations in Sediments

<190>
Botova, M.M., D.P. Malyuga, and U.I. Moiseyenko, Ministry of Geology and Conservation of Mineral Resources, Moscow, USSR; V.I. Vernadskii Institute of Geochemistry and Analytical Chemistry, Moscow, USSR; Academy of Sciences, Institute of Geology and Geophysics, Siberian Division, Novosibirsk. USSR

Experimental Use of Biogeochemical Method in Prospecting for Uranium Under Desert Conditions. Geochemistry 4:379-388. (1963)

> Geologic maps and sections were utilized to plot the results of biogeochemical prospecting for uranium in Permian sandstones and argillites from an arid region. It was found that the ash of plants that grew over a uranium deposit in sandstone usually contained more uranium than the soil; in some cases containing as much as 0.008 percent uranium. The uranium aureole determined from plant ashes was found to be greater in area than the aureole determined by radiometric surveying. The aureole was detectable in plants that grew over ore bodies lying at depths as great as 25 meters. Different plants accumulate different amounts of uranium. The oldest portion of a given plant accumulates the most uranium; leaves and the growing tips of branches contain the least uranium. (Auth) (JBT)

<191>
Brady, B.T., and B.S. Rice, USGS, Washington, DC

Helium Determination as an Exploration Technique at the Ambrosia Lake Uranium District, McKinley County, New Mexico. USGS OFR-77-669; 8 pp. (1977)

> Measurements of helium in soil gas, well water and mine air were made from samples collected near a roll-type uranium deposit in the Ambrosia Lake district, New Mexico. The purpose of this survey was to evaluate the potential of helium detection as an exploration technique in an area of known uranium mineralization. High helium values, which locally exceeded the volumetric atmospheric helium level by 400 ppb were measured from soil-gas samples collected during detailed sampling above Kerr-McGee Corporation's section 30 mine (T14N, R9W). Small amounts of excess helium in soil-gas and well water are easily detected, and may indicate the presence of previously unknown uranium-enriched horizons. In addition to the soil-gas and water samples, five samples of mine air were collected at a maximum depth of 230 m from well ventilated areas in the section 30 mine. The concentration of helium in the mine air exceeded the atmospheric level of 5239 ppb by 118 to 190 ppb. These data provide evidence that the helium concentration in the mine atmosphere is enriched by helium emitted from uranium orebodies, and from degassing mine waters which circulate through zones of uranium mineralization. (Auth) (MDW)

<192>
Bristol, M.

Uranium: The Exploration Rush Is On. Western Miner 49(5):12-28. (1976, May)

> With prices for uranium oxide (U3O8) in the $30/lb and higher range, uranium exploration in Canada is rapidly increasing. Renewed interest in uranium is focusing exploration attention on producing and non-producing areas in Saskatchewan, Ontario, Quebec, Manitoba, as well as in most of the other provinces and territories. This article details the exploration efforts in Canada, province by province, and the companies involved. (JBT)

<193>
Broxton, D.E., Los Alamos Scientific Laboratory, Los Alamos, NM

Uranium Hydrogeochemical and Stream Sediment Reconnaissance of the Dillon NTMS Quadrangle, Montana/Idaho, Including Concentrations of Forty-Three Additional Elements. GJBX-38(79); LA-7347-MS; 228 pp. (1979, March)

> A total of 1148 water and 1721 sediment samples were collected from 1796 locations in the Dillon quadrangle, Montana/Idaho. Samples were collected at a nominal density of one per 10 sq km except in the Boulder batholith area where the density was approximately one sample per 2 sq km. Surface waters were taken from flowing streams; ground waters were taken from springs and wells. All water samples were analyzed for uranium and 12 other elements. Sediment samples, collected from streams and springs, were analyzed for uranium, thorium, and 41 additional elements. The uranium contents of water samples range from below the detection limit of 0.02 ppb to 79.31 ppb. Most water samples having anomalously high uranium contents were collected in areas underlain by felsic rocks of the Boulder, Pioneer, and Idaho batholiths. Other groups of anomalous waters are associated with Belt metasediments in the Beaverhead and Salmon River Mountains and with Tertiary strata in intermontane basins. The uranium contents of sediment samples range between 0.95 and 130.50 ppm. Anomalous uranium values are associated with felsic rocks of Cretaceous batholiths and Belt quartzites near the Montana-Idaho border. Samples having uranium contents significantly above local background levels also occur in Tertiary strata adjacent to the anomalous areas in the crystalline terranes. Thorium concentrations in sediment samples range from 3.40 to 351.00 ppm. The average uranium/thorium (U/Th) ratio of samples with less than 20 ppm uranium is 0.37, whereas samples with uranium concentrations greater than 20 ppm have an average ratio of 1.85. The association of high uranium values with relatively high U/Th ratios may be a useful tool for identifying uranium-enriched terranes. (Auth) (PAG)

Uranium data for the Idaho portion of the quadrangle as well as multielement data for the entire quadrangle are open filed in this report for the first time. Uranium data for the Montana portion of the quadrangle were previously open filed in earlier reports by Broxton (1979) and Aamodt (1978). Listings of Field Data and Elemental Concentrations for Samples are contained in Appendix I. Histograms of Uranium Concentrations in Water and Sediment Samples and Thorium Concentrations in Sediment Samples are contained in Appendix II. Appendix III contains Standard Procedures and Codes used in this report.

<194>

EXPLORATION

<194>
Chaney, D.S., and S.L. Bolivar, Los Alamos Scientific Laboratory, Los Alamos, NM

Uranium Hydrogeochemical and Stream Sediment Reconnaissance of the Ekalaka NTMS Quadrangle, Montana. GJBX-55(78); LA-7069-MS; 71 pp. (1978, March)

A total of 710 water and 851 sediment samples were collected from 1347 locations at a nominal density of 1 location per 10 sq km. All water samples were analyzed by fluorometry and those with greater than 10 ppb uranium were reanalyzed by delayed-neutron counting. Sediment samples were analyzed by delayed-neutron counting. A value nominally twice the standard deviation above the mean was selected as the "anomaly threshold." By this criterion, 27 waters (19 wells, 5 springs, and 3 surface waters) and 33 sediments (26 dry streams, 4 wet streams, 2 wet springs, and 1 dry artificial pond) or about 4 percent of the combined water and sediment samples contained anomalously high uranium concentrations. Areas with anomalous uranium concentrations generally appear best delineated by a combination of water and sediment samples. The study delineated most known uranium occurrences. In addition, several areas of interest were identified. These are: (a) in the Belle Fourche shale formation and alluvium along Thompson Creek near the Black Hills uplift; (b) in the vicinity of Bay Horse/Moorhead in the Powder River Basin; and (c) in the Long Pine Hills area in the Williston Basin. A broad oval of anomalous sediment and water samples is found around the Ekalaka Hills and Long Pine Hills. The known radioactive mineralization is quite localized and low grade. The anomalous water samples indicate the presence of soluble uranium-bearing minerals. The principal hosts for the known deposits are arkosic sandstones (Fort Union or associated formations) and lignite beds. (PAG)

<195>
Cheadle, J.M., Jr., Los Alamos Scientific Laboratory, Los Alamos, NM

Data Management and Handline for the Hydrogeochemical and Stream Sediment Reconnaissance Program at the Los Alamos Scientific Laboratory. GJBX-22(78); 3 pp. (1978, January)

Since the spring of 1975, the Energy Systems and Statistics Group (S-12) at the Los Alamos Scientific Laboratory (LASL) has been involved in the data management aspects of the National Uranium Resource and Evaluation (NURE) Hydrogeochemical and Stream Sediment Reconnaissance (HSSR) program. The HSSR program is administered at LASL by the Geochemical Applications Group (G-5). This report is a description of the data management performed for G-5. (Auth)

<196>
Chenoweth, W.L., DOE, Grand Junction, CO

Exploration in Grants Uranium Region Since 1963. AAPG Bulletin 63(4):687. (1979, April)

The Grants uranium region is the largest uranium area in the United States. From 1951 through 1977, underground and open-pit mines produced 126,537 tons of uranium oxide U3O8. This amounts to 40 percent of the total United States uranium production. Ore reserves estimated by DOE for the region are 366,200 tons U3O8, or 53 percent of the domestic reserves in the 30 dollars forward-cost category. Since 1963, production in the Grants uranium region has expanded to the north and east largely owing to the efforts of exploration programs of major oil companies. During this period, average drilling depths have increased from approximately 200 to nearly 1,600 ft (60 to 960 m). Application of various geologic models is expected to assist in finding additional deposits, and the Grants uranium region is expected to maintain its position as the nation's principal source of uranium for years. (Auth)

<197>
Clayton, C.G., United Kingdom Atomic Energy Authority, Wantage Research Laboratory, Wantage, Berks, United Kingdom

Applications of Radioisotope X-Ray Fluorescence Analysers in Metalliferous Mineral Exploration and in Mining. CONF-691229; Nuclear Techniques for Mineral Exploration and Exploitation, Proceedings of a Panel, Krakow, Poland, December 8-12, 1969. International Atomic Energy Agency, Vienna, Austria, (pp. 59-72), 187 pp. (1971)

Equipment based on non-dispersive radioisotope X-ray fluorescence techniques is proving valuable in many analytical applications in mineral exploration and mining. Simplicity of operation, low cost, rugged construction, low radiation hazard, and acceptable limits of detection are among the factors which make this equipment practical. The continued development of radioactive sources and radiation detectors is enabling the range of applications to be extended and the introduction of solid-state detectors promise to allow simultaneous multi-element analyses to be carried out in the field or in a field laboratory. High-performance, battery-operated portable analysers for field use are available commercially and sufficient work has now been completed using the instruments on powdered artificial and natural ores to establish their value for routine use. Their true value for the analysis of rock faces and drill cores is still to be assessed. The development and application of radioisotope X-ray fluorescence bore hole probes, although still at a very early stage, appears to be very promising. (JMT)

EXPLORATION

<198>
Cook, J.C., Southwest Research Institute, San Antonio, TX

An Analysis of Airborne Surveying for Surface Radioactivity. Geophysics 17(4):687-706. (1952, October)

Quantitative estimates of the gamma radiation field intensities expected to be encountered in flight over various geologic bodies are presented. Scattering effects are included in the calculations, but several simplifying assumptions were necessary, such as assigning equal energies to all photons. Results are compared with geiger counter measurements of three kinds: near a small natural carnotite deposit, near a tenth-curie of radium, and soundings made over normal terrain at various times. It appears that anomalies from most outcrops of radioactive ores will exceed the normal fluctuations of background radiation due to topography, variations of composition of the surface, etc., only at altitudes of less than about 35 feet. However, such anomalies can probably be detected under favorable conditions by their characteristically pointed shape, allowing flight at higher elevations. Requirements on flight plan and instrumentation are discussed.

<199>
Dawson, H.E., and T.A. Weaver, Los Alamos Scientific Laboratory, Los Alamos, NM

Uranium Hydrogeochemical and Stream Sediment Reconnaissance of the Durango NTMS Quadrangle, Colorado. GJBX-10(79); LA-7346-MS; 111 pp. (1979, January)

A total fo 1519 water and 1604 waterborne sediment samples were collected from 1804 locations. The uranium concentrations in waters ranged from less than the detectable limit of 0.2 ppb to 25.7 ppb, with a mean value of 0.84 ppb. The concentrations in sediments ranged from 1.0 ppm to 71.6 ppm, with a mean value of 4.2 ppm. Thirty-four water samples (approximately 2.2 percent of the total water population) had uranium concentrations above 5.00 ppb, the highest of which were well water samples from the San Luis Valley. Thirty-seven sediment samples (approximately 2.3 percent of the total sediment population) had uranium concentrations above 12.0 ppm. The majority of these were taken from sites in Precambrian rocks, but several came from Paleozoic and mesozoic strata and Tertiary volcanics. The majority of the sediment samples with high uranium concentrations were stream sediments clustered in the Precambrian rocks exposed in the Needle Mountains. They were particularly high in the Vallecito Creek drainage area. (PAG)

Appendix A-Summary of Standard Procedures, Appendix B-Listings of Data for Water Samples, Appendix C-Listings of Data for Sediment Samples, Appendix D-Code to Data Listings, Appendix E-Individual Uranium Occurrences in the Durango Quadrangle

<200>
DeVoto, R.H., Colorado School of Mines, Department of Geology, Golden, CO

Uranium in Phanerozoic Sandstone and Volcanic Rocks. Uranium Deposits, Their Mineralogy and Origin, Short Course Handbook, Volume 3, M.M. Kimberley, (Ed.). University of Toronto Press, Toronto, Canada, Ch. 11, (pp. 293-306), 521 pp. (1978, October)

Uranium deposits in sandstones and volcanic rocks are discussed and exploration guides to uranium deposits in both rock types are given. In sandstone, the major exploration guides are: (1) fluvial sandstone, indigenously reduced, containing carbonaceous matter and pyrite; (2) abundant tuffaceous material or other uranium source within the host rock or nearby; (3) basin-margin uplift concurrent with sedimentation; (4) spatial proximity to an oxidizing environment. In volcanic rocks, the following exploration guides presently seem most important: (1) rhyolite or other acidic or alkalic rocks; (2) stratigraphic control on mineralization; (3) synvolcanic ground water hydrology, surface drainage, and topography; (4) pre-volcanic paleotopography; (5) early diagenetic ground water chemistry; (6) distribution of permeable beds and of fractures; (7) alteration patterns in the volcanic rocks. (JRD)

<201>
Dreschhoff, G., and E.J. Zeller, University of Kansas, Lawrence, KS

Uranium Resource Evaluation in Antarctica. AAPG Bulletin 63(3):441. (1979, March)

The continent of Antarctica is the only large land area on earth that has been left almost totally unexplored for uranium resources. In 1976 the first systematic uranium resource evaluation was started as part of the Antarctic International Radiometric Survey. Two areas in the Transantarctic Mountains and one area in Marie Byrd Land have been examined by airborne gamma-ray spectrometric methods. Most flight operations are conducted using Bell 212 helicopters. The equipment in use is a GeoMetrics GR-800 gamma-ray spectrometer with a GSI 512 detector and a GAR 6 analog-recorder. The equipment has proved to be satisfactory, and no plans have been made to increase detector size or to alter data acquisition systems owing to the extremely rigorous nature of the Antarctic field operations. (Auth)

<202>
Duncan, D.C., USGS, Washington, DC

Results of Reconnaissance for Uranium in Nonmarine Carbonaceous Rocks in Parts of California, Idaho, Nevada, Oregon, Utah, and Washington During 1951 and 1952. TEM-444A; 26 pp. (1953)

Nonmarine carbonaceous rocks, including lignitic shales, coal, and peat were tested at about 30 localities in California, Idaho, Nevada, Oregon, Utah, and Washington. Rocks ranging in age from Carboniferous to Quaternary were examined, although the principal attention was given middle and late Tertiary lignites of the northern part of the Great Basin. Most carbonaceous rocks examined contained essentially no uranium, but lignitic shales in the Goose Creek District, Idaho, a thin carbonaceous shale near Hagerman, Idaho, and a small peat deposits Davis County, Utah contained more than 0.003 percent uranium. (Auth)

<203>
Dunsmor, H.E., Canada Geological Survey, Ottawa, Ontario, Canada

Uranium Resources of the Permo-Carboniferous Basin, Atlantic Canada. Geological Survey of Canada Paper 77-1B, Report of Activities Part B, (pp. 341-348), 350 pp. (1977)

As part of the Uranium Resource Evaluation Program of the Canadian Geological Survey, a geological reconnaissance of the Permo-Carboniferous sedimentary basin of Atlantic Canada was conducted during 1976 to assess the potential U resources of the area. Numerous surface radioactive occurrences were discovered, none of them economic, but some of these surface clues may indicate subsurface economic deposits. A description and preliminary classification of the main occurrences were made: three types of deposit - Sandstone, Bituminous Shale, and Volcanogenic - and three styles of the Sandstone Type - Magdalen Islands, Prince Edward Island, and Pugwash-Tatamagouche - are represented. The Magdalen Islands Style of U mineralization is associated with elongate lenses of green-grey indurated sandstone occurring at the bases of thick sequences of poorly cemented red sands of the Permo-Carboniferous Cap-aux-Meules Formation (eolian?). U is directly associated with hydrocarbons filling fractures and pore spaces in the lenses. Specimens contain up to 2.15 percent U. The Prince Edward Island Style is restricted to that island and to the Cape Tormentine area of New Brunswick. Host rocks are upper Pictou Group (late Pennsylvanian) fluviatile sandstones and mudstones; mineralization is in the basal, coarse grained units, and reaches 250 ppm U in outcrop. The Pugwash-Tatamagouche Style is similar to the other two, but radioactivity is associated with coalified plant debris and with Cu mineralization. Occurrences are in the basal Pictou Group of northern Nova Scotia, Prince Edward Island, northwestern New Brunswick, and in southwestern Newfoundland (in the North Branch Formation, Codroy Group). The Bituminous Shale Type deposit is based on one outcrop near Hampton, N.B. and on geochemical and geophysical anomalies near Sussex. Mineralization is in the lower Carboniferous Albert Formation, which is composed of locally bituminous black shales, siltstones, sandstones, and minor limestones, with salt occurring locally near the top. Specimens of albertite from Hampton contain as much as 819 ppm U. Volcanogenic type deposits occur in Mississippian porphyritic rhyolites, foliated tuffs, and volcanogenic clastics of southwestern and northern New Brunswick. Mineralization is always associated with host rock alteration and the presence of a permeable conduit. Samples from Mt. Pleasant, N.B. contain up to 235 ppm U. Two other unclassified outcrops are along Ridge Brook, N.B., where concentrations of 82.7 ppm U have been found in grey, iron-stained argillites, and at Overfall Brook, Newfoundland, where a carbonaceous sand (Overfall Brook Formation) has been shown to contain up to 323 ppm U. (LKB)

<204>
Ferguson, R.B., Savannah River Laboratory, Analytical Chemistry Division, Aiken, SC

SRL-NSSR-Preliminary Raw Data Release - Greenville 1 Degree by 2 Degree NTMS Area, Georgia, North Carolina and South Carolina. GJBX-87(78); DPST-78-146-2; 181 pp. (1978, March)

Stream sediment samples were collected from small streams at 1813 sites and ground water samples were collected at 731 sites. Neutron activation analysis results are given for uranium and 16 other elements in sediments, and for uranium and 9 other elements in ground water. Key data from stream sites include (1) water quality measurements (pH, conductivity, and alkalinity (2) elements that may be related to potential uranium and thorium mineralization in this area (U, Th, Hf, Ce, and Dy), and (3) elements useful for geologic classification of the sample area (Ti, V, Fe, Mn, Al, and Sc). Supplementary data from stream sites include sample site descriptors (stream characteristics, vegetation, stream width, etc.) and additional elemental analyses that may be useful (P, Ba, Sm, La, Yb, and Lu). Key data from ground water sites include (1) water chemistry measurements (pH, conductivity, and alkalinity) and (2) elemental analyses (U, Na, Cl, Mg, Al, Mn, Br, V, and F). Supplementary data include site descriptors, information about the collection of the samples (well age, well depth, frequency of use of well, etc.), and analytical data for dysprosium. One uranium occurrence in the Greenville quadrangle is at the contact between the Toxaway gneiss and the Tallulah Falls Formation in the Blue Ridge Region of South Carolina. Uranium also occurs on the extension of the Warwoman lineament but appears to be related to the unconformity between the two rock units. The locality in Towns County, Georgia, is in a pegmatite and is a vein of radioactive garnet. (PAG)

<205>
Ferguson, R.B., E.I. Bancom, and V. Price, Savannah River Laboratory, Analytical Chemistry Division, Aiken, SC

Hydrochemical and Stream Sediment Reconnaissance: Raw Data Release V: Orientation Studies in the Spruce Pine, Moore, and Johnston, North Carolina Areas. GJBX-17(78); DPST-77-141-1; 92 pp. (1977, December)

The report presents raw data from the Spruce Pine, Moore, and Johnston, North Carolina, areas. Data from the Brush Creek study area are repeated in this report for user convenience. Uranium analyses were by neutron activation analyses. Other parameters measured are: alkalinity, conductivity, sulfate, nitrate and nitrite, orthophosphate, pH, Eh, dissolved oxygen, and temperature. Tables of water quality and field measurement data, tables of uranium and other elemental concentrations, sample locality maps, statistical summaries, and uranium distribution maps are included. (PAG)

<206>
Ferris, C.S., and B. Bennett, Ferris and Bennett Consulting, Arvada, CO

Geochemical Prospecting at the Ludwig Uranium Mine, Near Golden, Colorado. USGS Circular 753; Short Papers of the US Geological Survey Uranium-Thorium Symposium, 1977, J.A. Campbell (Ed.), (pp. 66-68), 75 pp. (1977)

The Ludwig uranium mine is located approximately 4.8 km northwest of Golden, Colorado in the Colorado Front Range. Country rock consists of gneisses and schists of the 1.8-2.0 b.y. old Idaho Springs Formation and a pegmatite, the 1.4 b.y. old Silver Plume Granite. The mine is within the northwest trending Hurricane Hill breccia reef fault zone, but no fault has been mapped within 600 m of the mine. The principal vein in the mine strikes northwest and is roughly at the contact of the pegmatite and garnet-biotite-quartz gneiss. A 1,000 square foot area on each side, centered on the old Ludwig shaft, was sampled for radioactivity and soil molybdenum content on a 25-foot grid. The central grid was surrounded by a zone 500 feet wide, in which samples were taken at 100-foot intervalas. Anomalies in parts of this zone led to further sampling at 25-foot intervals. Soil samples were analyzed for molybdenum, a known associate of pitchblende in Front Range uranium deposits and a more stable element than uranium in the weathering environment. There was a degree of correlation between radioactivity and molybdenum in some areas, but some molybdenum anomalies showed no significant radioactivity. The presence of molybdenum without radioactivity may be assumed to mean that soil cover retains or acquires molybdenum more easily than it retains or acquires the radioactive daughters of uranium. Trenching of molybdenum anomalies showed that most are related to narrow radioactive veins. Most veins were vertical and strike northwest. The strongest soil molybdenum anomaly corresponded to the westernmost northwest vein. Drilling showed that the vein extends farther southeast than the surface anomaly. This principal vein, not found by the original prospectors showed a molybdenum geochemical expression more prominent than the radiometric expression. (JMT)

<207>
Fitch, D.C., Ranchers Exploration and Development Company, Albuquerque, NM

Exploration Geology Methods in the Grants Mineral Belt. New Mexico State Bureau of Mines and Mineral Resources Circular 118; Selected Papers from 1970 Uranium Symposium at Socorro, New Mexico, R.J. Romat and D.R. Baker, Jr., Compilers, (pp. 13-28), 61 pp. (1971)

The paper summarizes uranium exploration methods for ore deposits in sandstone in the Morrison formation. The Grants mineral belt includes the deposits in the Laguna, Ambrosia Lake, Smith Lake, and Church Rock districts. The Morrison formation was deposited in a continental environment and consists of the Recapture Member, Westwater Canyon Member and Brushy Basin Member in the Grants mineral belt. The ore guides of general use in this area are: anomalous mineralization, color of host rock, position of area with respect to mineralized trends, presence of carbonaceous material and pyrite, bleaching of mudstone at base of host rock, relative host rock thickness, and stratigraphic environment of host rock. Current exploration practices involve using these criteria to outline favorable areas by drill data, and to a lesser extent, outcrop studies. (PAG)

<208>
Fitch, D.C., Ranchers Exploration and Development Company, Albuquerque, NM

Exploration for Uranium Deposits in Grants Mineral Belt, New Mexico. AAPG Bulletin 63(4):688. (1979, April)

Uranium ore deposits in the Grants Mineral Belt, New Mexico, occur in fluvial sandstones in the Jurassic Morrison Formation. Uranium mineralization is concentrated by a dark-gray to black substance that has been identified as humate derived from decaying vegetation. Black ore is truncated by overlying sandstone in at least two ore deposits, documenting an early age of mineralization. Ore deposits in the Grants Mineral Belt vary greatly in size and shape, generally occur in clusters, and often are difficult targets for drilling. Current exploration is largely a process of drilling in stages to (1) delineate favorable from unfavorable ground on a wide-spacing, (2) seek mineralization in favorable ground, and (3) conduct closely spaced drilling in mineralized areas. Criteria for favorability differ among exploration groups but generally includes (1) the presence of a host sandstone; (2) anomalous mineralization, (3) color of host rock, (4) presence of carbonaceous matter, and (5) position of area with respect to mineralized trends. A description of the sequence of drilling, from ore discovery to a mine on a one-square mile area at the Johnny M uranium deposit located in the east part of the Ambrosia Lake District, provides an example of the problem of predicting ahead of discovery where in a certain area, orebodies may occur. A study of the drill data at the Johnny M indicates that uranium ore is not related to specific features other than the presence of humate which is commonly associated with coalified plant fragments in mudstone-rich parts of the host sandstone. (Auth)

EXPLORATION

<209>
Fleischer, R.L., and A. Mogrocampero, General Electric Research and Development Center, Schenectady, NY

Radon Emanation Over Orebody: Has Long-Distance Transport of Radon Been Observed?. AAPG Bulletin 63(4):688. (1979, April)

A major hope for discovering subsurface uranium ore is that measurable concentrations of the radioactive gas Rn 222 can be recognized near the surface of the earth. Integrated measurements, made over several weeks, show promise of giving greater reproducibility than short-term measurements, which are more subject to meteorologic variability. The use of improved methods of integrated radon measurements--free of Rn 220, of thermal-track fading, and of moisture-condensation effects--allow readings to be made that generally are highly stable over time. At a site 16 km north of Thoreau, New Mexico, readings at a depth of 63 cm, taken over a 9-month interval for a set of 55 positions, give different but nearly constant monthly readings at each position, the typical standard deviation being 14 percent. Superimposed on that stable pattern have been two periods during which spatially grouped radon readings increased by a factor of two or more over their normal values. The simplest tenable description of the source of the increases is sporadic puffs of upflowing gas, originating at as yet unknown depths. The measurements are consistent with an upward velocity of flow of approximately 10(E-2) cm/sec. (Auth)

<210>
Foy, M.F., and J.E. Gingrich, Terradex Corporation, Walnut Creek, CA

A Stream Sediment Orientation Program for Uranium in the Alligator River Province, Northern Territory, Australia. Journal of Geochemical Exploration 9:357-364. (1977)

Sediment samples were collected from streams draining the Koongarra uranium deposit and the small uranium mines in the South Alligator Valley. Determinations for uranium, copper, and lead on various size fractions taken from each of the samples indicated that the best results were obtained for uranium from the minus 200-mesh fraction, but the train from the Koongarra ore deposit was very short. Copper and lead were not found to be very useful as indicator elements for uranium. Alpha-track films were used to determine the radon content of each sample and the ratio of alpha-track film reading to uranium content was found to define anomalous drainage areas around the mineralization in the Koongarra area. The areas so defined were of sufficient magnitude to be defined in a reconnaissance stream sediment program. (Auth)

<211>
Foy, M.F., and V. Miezitis, Atomic Energy Commission, Uranium Branch, Exploration Division, Lucas Heights, N.S.W., Australia

Uranium Mineralization at Anomaly 2J, South Alligator Valley, Northern Territory, and its Significance Concerning Regional Structure and Stratigraphy. The Australian Institute of Mining and Metallurgy Proceedings 261:1-11. (1977, March)

A weak airborne radiometric anomaly was examined in the field and the presence of uranium confirmed. Rotary-percussion drilling showed the presence of uranium but a subsequent programme of diamond and rotary-percussion drilling indicated that the concentration of uranium was uneconomic. Within the tuffs and volcanics of the prospect the uranium existed as uranyl phosphates within the oxidized zone. Geological mapping and the diamond drill core showed that the Star Creek Volcanics are part of the Lower Proterozoic Masson Formation, probably with member status, rather than the expression of an Archaean basement ridge. This change in the interpretation of the fundamental struture of the Pine Creek Geosyncline has led to a reexamination of the stratigraphy and to suggestions which differ from the current concept. (Auth)

<212>
Fraser, H.J., Australian Atomic Energy Commission, Research Establishment, Lucas Heights, Australia

Direct Current Stabilization of Scintillation Counters used for Uranium Prospecting. Nuclear Instruments and Methods 136(3):513-516. (1976, August)

A simple system for stabilizing a scintillation counter is described which uses a dc light source (green light-emitting diode) to illuminate the photo-cathode of the photomultiplier used to detect gamma-induced light pulses from the scintillator. Basically, the photomultiplier anode current due to the light-emitting diode light is held constant by an automatic control loop acting on the voltage to keep the gain of the photomultiplier tube constant. However, because the temperature coefficient of the scintillator does not in general match that of the light emitting diode, further compensation is required to achieve constant gamma pulse gain. This is provided by adding to the control circuit a current derived from the light emitting diode voltage which is an excellent measure of temperature; the use of this technique results in gain constancy to within (plus or minus) 1 percent in the 10-50 C ambient temperature range. Noise and countrate limitations are discussed and it is concluded that the system is generally applicable to uranium prospecting equipment. (Auth)

<213>
Galipeau, J.M., and P.C. Ragland, Savannah River Laboratory, Aiken, SC

A Radiometric Study of Rocks in Three Selected Drainage Basins in the Spruce Pine Area, North Carolina. DP-1454; GJBX-30(78); 79 pp. (1977, December)

Pilot studies to investigate the areal extent of U dispersion halos in stream waters and sediments were conducted in three drainage basins near Spruce Pine, NC. The Big Crabtree, Brush, and North Harper Creek basins are underlain by Precambrian and lower Paleozoic metamorphic and igneous rocks. Topography is mature, drainage dendritic. Work consisted of a field survey of total gamma activity, rock sample analyses for U, Th, and K, autoradiography, and petrographic and mineralogic studies. It was found that total radioactivity correlated better with lithology than soil group, soil parentage, or topography. Data was grouped into three populations based on lithology; they are: (1) mica gneiss and hornblende gneiss, mean activity 60.23 cps; (2) mica schist, alaskite, pegmatite, and Grandfather Mountain Formation, mean activity 98.18 cps; and (3) Wilson Creek Gneiss, mean activity 203.46 cps. Populations 2 and 3 may actually each consist of two populations. U concentrations were 0.05-67.5 ppm for the Big Crabtree Creek, 0.32-251 ppm for the Brush Creek, and 1.99-50.5 ppm for the North Harper Creek basins. Gamma anomalies coincided with known areas of U-mineralization. The U/K 40 ratio was found to be the best parameter for identification of U-mineralized samples. Autoradiographic studies indicate that uraniferous minerals in most of the rocks from these basins are primary, and will therefore tend to accumulate in detrital sediments as placers rather than being leached and transported. (LKH)

<214>
Givens, W.W., R.L. Caldwell, and W.R. Mills, Jr., Mobile Oil Corporation, Dallas, TX

In-Situ Assaying for Uranium in Rock Formations. U.S. Patent 3,686,503; 7 pp. (1972, August)

A new technique of in situ assaying for ore-grade uranium by detection of delayed fission neutrons is described. A device consisting of a 14 Mev neutron source and detector is lowered into an exploration hole. The formation of interest is cyclically irradiated with neutrons, and a record made of delayed neutrons emitted by neutron fission of uranium. In this way, a measure of U can be obtained which is unaffected by disequilibrium. Induced Th emission will normally be minor. To reduce the effects of activated O 17, the procedure of first establishing an O 17 background from a known non-uranium-bearing rock unit is used. (LKH)

<215>
Gorski, L., Academy of Mines and Metallurgical Sciences, Institute of Nuclear Techniques, Krakow, Poland

Solid-State Detectors and Electronics in Gamma and X-Ray Spectrometry. CONF-691229; Nuclear Techniques for Mineral Exploration and Exploitation, Proceedings of a Panel, Krakow, Poland, December 8-12, 1969. International Atomic Energy Agency, Vienna, Austria, (pp. 103-114), 187 pp. (1971)

The superior energy resolutions of solid-state detectors offers an excellent advantage for gamma and X-ray spectrometry. At present only two types of solid-state detectors are generally available, namely the lithium-drifted germanium and lithium-drifted silicon semiconductors, and both require cryogenic cooling. The high resolution potential of these detectors is being realized more fully through recent improvements in the design of the associated electronic circuitry and cooling devices. The need for cryogenic cooling of the present detectors and the first amplifier stage is not considered as a significant practical drawback, although it imposes a certain degree of limitation on field applications. Some basic knowledge of the techniques is reviewed. (Auth)

<216>
Grasty, R.L., Canada Geological Survey, Ottawa, Ontario, Canada

Uranium Measurement by Airborne Gamma-Ray Spectrometry. Geophysics 40(3):503-519. (1975, June)

When window-type gamma-ray spectrometers are used in the airborne measurement of uranium, it is necessary to correct for scattered high energy radiation from thallium 208 in the thorium decay series. This radiation can be scattered in the crystal, in the ground, and in the air. A theory is presented that can adequately explain the spectrum buildup in the uranium window for a point source of thorium oxide immersed to different depths in water and for a detector above the water. The theory is extended to predict the buildup as a function of altitude for detectors of different sizes and shows that errors in the airborne measurement of uranium can be significant if no allowance is made for radiation scattered in the ground and in the air. (Auth) ([illegible])

<217>
Gregg, C.C., AEC, Grand Junction, CO

Reconnaissance and Investigational Drilling on Hoskinnini and Nokai Mesas, San Juan County, Utah, and Navajo County, Arizona. RMO-987; 9 pp. (1952, November)

Uranium reconnaissance drilling was conducted on Nokai Mesa, Arizona and Hoskinnini Mesa, Utah in 1952. Strata intersected ranged from the Cedar Mesa Sandstone member of the Cutler Formation (Permian) to the Navajo Sandstone (Jurassic). The inconsistency and low-grade nature of the mineralization makes further work inadvisable, though the extensive channels in the Shinarump Formation may merit future investigation. Mineralization is in a paleo-channel at the contact between the Moenkopi Formation and the Shinarump Conglomerate. The channel bottom is a conglomerate of chert, jasper, and other pebbles, with occasional copper coloring and sometimes with alteration or carbonization. The channel sands are up to 160 feet thick and several hundred feet wide. In a few places the conglomerate contains pyrite, chalcopyrite, chalcocite, and bornite. U-mineralization usually occurs in a roll or gouge where logs and organic trash collected; important associations appear to be organic carbon and copper, usually as malachite. A muddy siltstone layer of the Moenkopi Formation underlies every U show, and may be an important ore control. One hole on Nokai Mesa showed carnotite-copper mineralization. (LKH)

<218>

EXPLORATION

<219>
Harms, T.F., and F.N. Ward, USGS, Washington, DC

Determination of Selenium in Vegetation. USGS Bulletin 1408; New and Refined Methods of Trace Analysis Useful in Geochemical Exploration, F.N. Ward, (pp. 37-42). (1975)

The amount of selenium concentrated in vegetation can be a useful indicator of conceal uranium ore bodies in soils or rocks supporting the vegetation and it can provide a basis for studying the effect of the natural environment on man and animals. When selenium content of forage crops is below 0.04 ppm, animals suffer from a selenium deficiency, and when the selenium content exceeds 4 ppm, animals suffer from selenium toxicity. These limits indicate the range for which any method of determining selenium in vegetation has to be useful. In this report, selenium in vegetation was determined, after wet ignition under reflux with a hot mineral-acid mixture, by the reaction of selenium with 2,3-diaminoaphthalene to form 4,5-benzopiazselenol, whose florescence is proportional to the selenium concentration. The reaction is sensitive to about 0.02 microgram of selenium and, accordingly, the lower limit of the method is 0.02 ppm. Recoveries of added selenium are about 90 percent, and the relative standard deviation is on the order of 10-15 percent. (JMT)

<219>
Heffner, J.D., and R.B. Ferguson, Savannah River Laboratory, Analytical Chemistry Division, Aiken, SC

Preliminary Raw Data Release, Charlotte 1 Degree X 2 Degree NTMS Area, North Carolina and South Carolina. DPST-78-146-1; GJBX-40(78); 31 pp. (1978, January)

The report presents preliminary results of stream sediment and ground water reconnaissance in the Charlotte National Topographic Map Series 1 degree x 2 degrees quadrangle. Stream sediment samples were collected from small streams at 1254 sites for a nominal density of one site per 13 square kilometers in rural areas. Ground water samples were collected at 759 sites for a nominal density of one site per 25 square kilometers. Neutron activation analysis results are given for uranium and 16 other elements in sediments, and for uranium and 9 other elements in ground water. Field measurements and observations are reported for each site. Analytical data and field measurements are presented in tables and maps. Statistical summaries of data and a brief description of results are given. A generalized geologic map and a summary of the geology of the area are included. (Auth)

<220>
Jacobsen, S.I., P.L. Aamodt, and R.R. Sharp, Jr., Los Alamos Scientific Laboratory, Los Alamos, NM

Uranium Hydrogeochemical and Stream Sediment Reconnaissance of the Lime Hills and Tyonek NTMS Quadrangles, Alaska, Including Concentrations of Forty-Three Additional Elements. GJBX-29(79); LA-7348-MS; 228 pp. (1979, January)

Water and sediment samples were collected from 1250 streams and small lakes in the Lime Hills and Typnek quadrangles, Alaska. The uranium contents of the 671 waters from the Lime Hills quadrangle range from below the detection limit of 0.02 ppb to a high of 11.29 ppb. Uranium contents of the 667 sediments from this quadrangle range from a low of 0.1 ppm to a high of 94.9 ppm. Both waters and sediments containing relatively high uranium concentrations are found to cluster in association with plutonic rocks in the Alaska Range, and particularly so in the vicinity of the Tired Pup batholith and Mount Estelle pluton. The uranium contents of 575 waters from the Tyonek quadrangle range from below detection limit to 13.13 ppb. Relatively high uranium concentrations in waters were found to cluster near the Mount Estelle pluton and undifferentiated igneous, metasedimentary, and volcanic rocks in the Alaska Range and in Pleistocene deposits along the Castle Mountain fault. Uranium contents in 502 sediments from the Tyonek guardangle range from 0.1 ppm to 58 ppm. Most sediment samples having high uranium concentrations are from locations near the Mount Estelle pluton and Styx River batholith in the Alaska Range. Data for samples collected in the Alaska Range and the two flanking lowlands were also examined separately. Water samples from all source types in the Alaska Range had a higher mean uranium concentration (0.85 ppb) than those from the Western Lowland (0.34 ppb) or the Susitna Lowland (0.51 ppb). The mean uranium concentrations for lake water samples from the Alaska Range and the lowland areas are similar. Sediment samples from streams and lakes in the Alaska Range have a markedly higher mean uranium concentration (7.00 ppm) than sediment samples from either the Western Lowland (2.45 ppm) or the Susitna Lowland area (1.73 ppm). (Auth)(PAG)

Water samples were analyzed for uranium and 12 additional elements; sediment samples were analyzed for uranium and 42 other elements. This report addresses only uranium and thorium. Appendix I - Listings of field data and elemental concentrations for samples from the Lime Hills quadrangle. Appendix II - Listings of field data and elemental concentrations for samples from the Tyonek quadrangle. Appendix III - Listings of dissolved oxygen in waters measured at sample locations in the Lime Hills and Tyonek quadrangles. Appendix IV - Histograms of uranium concentrations in waters and sediments from three physiographic provinces covered by the Lime Hills and Tyonek quadrangles. Appendix V - Summary of standard procedures, explanation of codes, and key to sample types listed in Appendixes I and II.

<221>
Killsgaard, T.H., V.L. Freeman, and J.S. Coffman,
USGS, Washington, DC

Mineral Resources of the Sawtooth Primitive Area,
Idaho. USGS Bulletin 1319-D; 174 pp. (1970)

A mineral survey of the Sawtooth Primitive Area and vicinity, Idaho, was made in 1966, 1967, and 1968 by the USGS and the U.S. Bureau of Mines. The area studied was in the rugged Sawtooth Range of south-central Idaho and consisted of about 314 square miles of the officially designated Sawtooth Primitive Area, plus adjoining areas that aggregate an additional 120 square miles. An unexpected result of the geochemical sampling in the area was the discovery of concentrations of uranium in many stream-sediment samples. A high proportion of these samples came from the headwaters of the South Fork Payette River; from streams draining the rocks of the Sawtooth batholith. Visual and radiometric examinations of the Sawtooth outcrops disclosed minor showings of accessory minerals that could contain uranium, but no veins or concentrations of uranium-bearing minerals were found. Uranium in the Sawtooth batholith seems to be present partly in the mineral euxenite and probably also in some other form. Euxenite was tentatively identified as the fine-grained radioactive mineral found in a pegmatite within the Sawtooth batholith. Another type of uranium occurrence is represented by the unusual amounts of uranium found in black muds and clays, and in bog samples high in organic matter. (JRT)

<222>
Lesure, F.G., J.M. Motooka, and P.L. Weis, USGS,
Reston, VA; USGS, Denver, CO

Exploration Geochemical Studies of Some Sandstone
Copper-Uranium Deposits, Bradford, Columbia, and
Lycoming Counties, Pennsylvania. Journal of
Research of the USGS 5(5):609-621. (1977,
September)

Semiquantitative spectrographic analyses of mineralized and unmineralized sandstone, siltstone, and claystone from the Catskill formation of Devonian age in Bradford, Columbia, and Lycoming Counties, Pennsylvania, suggest that copper, silver, and uranium are the principal metallic elements concentrated in the mineralized rock. Lead, mercury, and molybdenum may be concentrated slightly in mineralized rock but values are too low to be of use in exploration. The deposits are too small to make large anomalies in stream sediments except in drainage basins of less than a few acres. However, if a large deposit were exposed to weathering, it would probably be detectable by stream sediment sampling. (Auth)(MBW)

<223>
Lueck, S.L., D.D. Runnels, and G. Markos.
University of Colorado, Department of Geological
Sciences, Boulder, CO

Computer Modelling of Uranium Species in Natural
Waters: Applications to Exploration.
Proceedings of the Joint Annual Meeting of the
Geological Association of Canada, the
Mineralogical Association of Canada, and the
Geological Society of America, Toronto, Ontario,
October 23-26, 1978. The Geological Society of
America, Boulder, Colorado, (p. 448), 531 pp.
(1978)

The WATEQF computer program has been modified to include 21 aqueous species and 17 minerals of uranium. Input consists of quantitative chemical analyses of the waters of interest, together with field measurements of Eh, pH, and temperature. In absence of field Eh data, estimates are made. This form of modelling may find use in geochemical exploration, solution mining, and pollution control. Calculated saturation indices permit immediate application of the program to hydrogeochemical exploration for deposits of uranium. Analyses of groundwaters from known uranium deposits in Wyoming and Texas were supplied by Wyoming Minerals Corporation. Calculated saturation indices show supersaturation of the groundwaters with respect to uraninite and coffinite. Widspread haloes of other minerals are also indicated around the deposits, serving as a guide to ore. (Auth)

<224>
Maxwell, J.C., Los Alamos Scientific Laboratory,
Los Alamos, NM

Results of Uranium Hydrogeochemical and Stream
Sediment Reconnaissance of the San Juan Area,
Southwestern Colorado. LA-UR-77-1152; 23 pp.
(1977, March)

Over 1700 water samples and nearly 2000 sediment samples were collected from 1995 sites in the San Juan Mountains, Colorado, during June and July, 1976, by the Los Alamos Scientific Laboratory for the ERDA National Uranium Resource Evaluation project. Most of the water samples were fluorometrically analyzed for uranium, a few of the higher uranium concentrations (greater than 10 ppb) of water samples and all the sediment samples were analyzed by delayed neutron counting. Average uranium values for the water samples taken from mountains was less than 0.5 ppb, from plateaus was 1-2 ppb, and from Mancos shale areas exceeded 2 ppb. Anomalous sediment samples came from the Storm King Peak area and upper Vallecito Creek, with values of 40 ppm. The Lake City mining district area contained samples with 4-30 ppm uranium in the sediment and 3-30 ppb in the water. (MSB)

EXPLORATION

<225>
Morris, W.A., H.E. Bunker, and D.W. Steinhaus, Los Alamos Scientific Laboratory, Los Alamos, NM

Hydrogeochemical and Stream Sediment Reconnaissance of the National Uranium Resource Evaluation Program - The Rocky Mountain States of New Mexico, Colorado, Wyoming, and Montana and the State of Alaska, October-December 1977, A Progress Report. LA-7175-PR; GJBX-77(78); 10 pp. (1978, May)

During the first part of the quarter, October-December 1977, the scope of the Hydrogeochemical and Stream-Sediment Reconnaissance (HSSR) survey was expanded by the Department of Energy (DOE) to include the analysis of thorium and lithium in sediment and several other elements selected by the Los Alamos Scientific Laboratory (LASL) in either sediment or water. Development of the LASL multielement capabilities in the x-ray fluorescence, spectrochemical, and neutron activation techniques was accelerated to achieve the required throughtput rate of 200 samples per day by each method early in FY 1978. The LASA Will report data for 43 elements in sediment samples and 13 elements in water samples. During the quarter, uranium analyses were determined for 7360 sediment samples and 7100 water samples. The priorities and format for HSSR reconnaissance reports were changed to reflect the new DOE guidance received early in the quarter. Reconnaissance report boundaries will coincide with those of the NTMS 1:250,000 scale topographic map sheets; existing data bases are being split and combined to conform to these boundaries. Computer output formats and headers for the multielement listings to be used in LASL HSSR reports were developed and are ready for use on the first multielement report. One reconnaissance report was open filed through the DOE Grand Junction Office. Two NTMS quadrangles were sampled as part of pilot studies; 39 of the 66 quadrangles assigned to the LASL in the lower 48 states have been completely sampled, and bid quotations were requested for sampling all of the remaining parts of the other 27 quadrangles during FY 1978. Sampling specifications to be released for bid next quarter were prepared for the 35 quadrangles to be sampled in Alaska in FY 1978. (Auth)

<226>
Moxham, R.M., USGS, Washington, DC

Geologic Evaluation of Airborne Radioactivity Survey Data. Peaceful Uses of Atomic Energy, Vol. 2, Survey of Raw Material Resources, Proceedings of the 2nd International Conference, Geneva, Switzerland, September 1-13, 1959. United Nations, New York, (pp. 815-819), 843 pp. (1958, September)

Recent development of large-volume crystal detectors for aerial radioactivity surveying and application of semiquantitative analytical techniques now permit geologic evaluation of regional surveys whereas previous qualitative surveying methods were generally limited to direct ore-finding techniques. Data obtained by the U.S. Geological Survey's airborne detector are discussed and the conclusions drawn are generally valid for any scintillation detector of comparable crystal volume and energy response. (JMT)

<227>
O'Connor, L.J., and B.D. Smith, USGS, Denver, CO

Total-Field Magnetic Surveying as an Exploration Tool for Sedimentary Uranium Deposits. USGS Circular 753; Short Papers of the US Geological Survey Uranium-Thorium Symposium, 1977, J.A. Campbell (Ed.), (pp. 13-15), 75 pp. (1977)

Total-field magnetic surveying is a relatively simple and inexpensive geophysical exploration method. In order to test applications in the exploration for sedimentary uranium deposits, ground surveys were conducted over several areas of known mineralization. Two surveys were conducted in northern Colorado over roll fronts in the Upper Cretaceous Laramie Formation. One survey was made on exposed Laramie with a roll front occurring in a sand unite approximately 15 m below the surface. A strong correlation was found between a sharp 15-gamma negative anomaly and the mineralized zone. This anomaly probably resulted from the relative depletion of magnetic minerals in the vicinity of the roll front. A second survey was made where approximately 45 m of the White River Formation unconformably overlies the Laramie. Here mineralization occurs in the Laramie about 75 m below the surface. No magnetic anomalies could be directly associated with the ore. The lack of any distinctive magnetic pattern may have been due to the greater depth of the deposit, or to the absence of those conditions that produced the relatively low magnet values of in the previous case. Two surveys were also conducted in the Powder River Basin of Wyoming. One survey in the central portion of the basin was directed at uranium deposits 45-50 m deep in the Eocene Wasatch Formation. A small negative anomaly correlated with the oxidized side of the zone mineralization. The other area surveyed had uranium mineralization in the Fort Union and Wasatch Formations, ranging from near surface to deeper than 150 m. Here the magnetic pattern was complex and uranium deposits were not marked by any consistent magnetic pattern. The depth, size, and magnetic properties of mineralization and the influence of local geologic features are controlling factors on the magnetic patterns observed in the surface surveys. Despite the complexities introduced by these local factors, total-field magnetic surveying, involves only one or two people with commercially available instruments and it is a rapid and inexpensive exploration tool for sedimentary uranium deposits. (JMT)

<228>
Parslow, G.R., and I. Dwairi, University of Regina, Department of Geological Sciences, Regina, Saskatchewan, Canada

Extraction of Uranium Ions from Water: A Rapid and Convenient Method Using Prepackaged Ion Exchange Resins. Journal of Geochemical Exploration 8:581-587. (1977)

A new method of extracting and concentrating U ions from aqueous solutions in the field using ion exchange resins in teabags is described. Field extraction saves shipping costs and avoids problems with "aging" of water samples. Teabags are the only commercially available containers that fullfill the requirements for field use of resins. The resin used is Dowex 1 X8, converted to either the hydroxide or sulfate form and stored as batches of 50 teabags, 3g of damp resin per bag, in sealed polyethylene bags. Resin particles should be no smaller than 60-80 mesh, 20-50 mesh being the most convenient. Water samples are acidified to 1-2 pH, extracted, the teabags agitated and eluted. It is possible to determine U values of less than 0.1 ppb using this technique. The technique is useful in U extraction from acid digests of lake sediments; Fe quench effects are essentially eliminated. The method also has application in other fields simply by changing the resin and reagents. (LKH)

<229>
Petee, G.I.

Methodes Nucleaires Utilisees Pour la Prospection et L'Exploitation des Ressources Minerales non Petrolieres. CONF-691229; Nuclear Techniques for Mineral Exploration and Exploitation, Proceedings of a Panel, Krakow, Poland, December 8-12, 1969. International Atomic Energy Agency, Vienna, Austria, (pp. 37-57), 187 pp. (1971)

The applicability of nuclear borehole methods for non-petroleum mineral resources prospecting is now being recognized. The information obtained through these methods is an aid to geological studies for the discovery and evaluation of ore and mineral salt deposits. In general, the borehole methods for these types of investigation could be adapted from those most commonly employed in the petroleum industry. Nuclear borehole methods are based on one or more of the following techniques or disciplines: measurement of natural radioactivity, gamma-ray scattering, photo-neutron reactions, radioisotope X-ray fluorescence, thermal and fast neutron activation, fast neutron inelastic scattering, thermal neutron capture and cyclic activation. An analysis is given on the performance and limitations of the methods and their applicability for deposit prospecting of potash salt, coal and ores of low, medium and high atomic mass elements. (Auth)

<230>
Price, V., and R.B. Ferguson, Savannah River Laboratory, Analytical Chemistry Division, Aiken, SC

Preliminary Basic Data Release - Ground Water in Winston-Salem 1 Degree by 2 Degree NTMS Area, North Carolina, Virginia, and Tennessee. GJBX-58(78); DPST-78-146-3; 95 pp. (1978, March)

Ground water samples were collected at 780 sites in the Winston-Salem NTMS quadrangle for a nominal density of one site per 25 sq km. Uranium and other elements were determined by neutron activation analysis. Key data from ground water sites include (1) water quality measurements (pH, conductivity, and alkalinity) and (2) elemental analyses (U, Na, Cl, Mg, Al, Mn, Br, V, and F). Supplementary data include site descriptors, information about the collection of the samples, and analytical data for dysprosium. Maximum reported uranium concentration was 4.01 ppb, minimum reported value was 0.001 ppb and the mean value was 0.116 ppb. Standard deviation is 0.30. (PAG)

This report is a supplement to GJBX-66(77), DPST-77-146-1, which contained a geologic description of the area and analytical results for stream sediment samples.

<231>
Price, V., and P.L. Jones, Savannah River Laboratory, Analytical Chemistry Division, Aiken, SC

Orientation Study Data Release VI: Leesville, South Carolina Area. GJBX-61(78); DPST-78-181-1; 39 pp. (1978, March)

Water and stream sediment samples were collected from the upper Coastal Plain, Modoc Fault Zone, Kiokee Belt, and the Carolina State Belt. Cuttings were collected from water wells being drilled in the area. This report includes sample locality maps, uranium distribution maps, tables of water quality and field measurement data, and tables of uranium and other elemental concentrations. (PAG)

This paper presents only raw data. Field data are presented in two parts: Tables 1 and 2 contain a record of site description data and Tables 3 and 4 contain a listing of field analytical data.

<232>
Purson, J.D., and R.D. Warren, Los Alamos Scientific Laboratory, Los Alamos, NM

Uranium Hydrogeochemical and Stream Sediment Reconnaissance of the La Junta NTMS Quadrangle, Colorado, Including Concentrations of Forty-Three Additional Elements. GJBX-41(79); LA-7343-MS; 182 pp. (1979, February)

Totals of 1351 water and 656 sediment samples were collected from 1532 locations. Water samples were collected from wells, streams, and springs; sediment samples were collected from streams and springs. The uranium concentrations in waters range from below the detection limit of 0.02 ppb to 748.40 ppb, with a mean uranium concentration for all water types of 7.22 ppb. Five clusters of samples containing relatively high uranium values are defined; they are associated with the Dakota sandstone-Purgatoire formations, the Morrison formation, or alluvium near the Arkansas River. The cluster associated predominantly with the Morrison formation has the most favorable lithologic and structural setting for possible uranium mineralization. Sediments collected in this study have uranium concentrations that range between 1.60 ppm and 52.20 ppm, with a mean of 4.54 ppm. The majority of sediment samples with relatively high uranium concentrations were collected in four areas that are associated with either the Dakota-Purgatoire formations or the Graneros shale-Greenhorn limestone-Carlile shale formations. The cluster of samples containing the highest uranium values for sediments and the cluster containing the highest uranium values for waters are coincident and are located in the west-central portion of the quadrangle. (Auth) (PAG)

Appendix I-A: Listings of Field Data and Elemental Concentrations for Water Samples, Appendix I-B: Listings of Field Data and Elemental Concentrations for Sediment Samples, Appendix II: Histogram of Thorium Concentrations in Sediments, Appendix III: Summary of Standard Procedures and Codes Used and Key to the Sample Types Listed in Appendix I

<233>
Reade, H.L., Jr., Resource Associates of Alaska, Fort Collins, CO

Grover Uranium Deposit: A Case History of Uranium Exploration in the Denver Basin, Colorado. The Mountain Geologist 13(1):21-31. (1976, January)

In the northwestern portion of the Denver Basin, Weld County, Colorado, exploration was successful in the discovery of "Wyoming-type" solution front uranium deposits in sandstones of the Upper Cretaceous Fox Hills and Laramie Formations. These deposits, although low in grade and small in size, varying from a few thousand to one million pounds of U3O8, are commercially significant due to price increases for uranium. The Grover uranium deposit, discovered in 1970, contains an estimated reserve of 1,007,000 pounds with an average grade of 0.18 percent U3O8. This deposit occurs in a medium- to fine-grained carbonaceous, feldspathic, fluvial, channel sandstone of the Laramie Formation. Exploration in the Grover area was guided by a system of radiometric log interpretations similar to that developed in the Powder River Basin, Wyoming. This system was used because alteration of the sandstone was not readily identified in well cuttings. Sand isopach maps were also utilized to control exploration because mineralization was found to be related to changes in sand thickness. The configuration of the geochemical cell in the Grover area established that uraniferous fluids moved in a northwest direction. Uranium precipitation was caused by the downdip migration of oxygenated groundwater high in uranium content that moved through the Grover Sandstone, a highly carbonaceous, pyritic sandstone. (JHT)

<234>
Reynolds, R.L., and M.B. Goldhaber, USGS, Denver, CO

Recognition of Oxidized Sulfide Minerals as an Exploration Guide for Uranium. Journal of Research of the USGS 6(4):483-488. (1978, July)

The difference in color between oxidized and reduced sandstones has been used as an exploration guide for roll-type U deposits. The grey zones of reduced sandstone as a rule contain pyrite and marcasite as anhedral to euhedral crystals and crystal aggregates, as interstitial cements, and as replacements and overgrowths of detrital Fe-Ti oxides and fossil vegetal matter. These are oxidized to limonite by groundwaters during ore formation. Processes other than oxidation of sulfides, however, can cause reddening of clastic sediments without the creation of a redox boundary. Other sources include intrastratal alteration of Fe-bearing silicates and oxides and deposition of clay size ferric oxides. Therefore criteria for distinguishing ferric oxides and hydroxides formed by oxidation of Fe-sulfides are needed. Samples from 4 districts were tested: Morrison Formation (Upper Jurassic), Grants Mineral Belt, N.M.; Wasatch Formation (Eocene), Powder River Basin, WY; Whitsett Formation (Eocene), Karnes Co., TX; and Catahoula Tuff (mid-Tertiary), Webb Co., TX. All except Morrison contain a roll-type ore body. Samples were studied as polished grain mounts and thin sections in reflected light. Diagnostic features of limonite from sulfide oxidation are: (1) limonite pseudomorphs after Fe-sulfides; (2) limonite from sulfidized plant debris; (3) limonite from sulfidized Fe-Ti oxide minerals showing retention of characteristic textures of the original detrital grain titanomagnetite commonly has ilmenite along the (111) crystallographic planes - sulfidization commonly leaves remnants of ilmenite lamellae with characteristic (111) orientation); (4) characteristic internal textures in limonite indicative of oxidized sulfide cement (limonite formed by replacement of Fe-sulfide cement is characterized texturally by convolute patterns composed of intergrowths of different Fe-oxide and hydroxide phases - polished sections from 3 unmineralized sandstones reddened by intrastratal alterations show no convolute textures). At least two of these diagnostic features was found in each of the deposits studied. (LKH)

EXPLORATION

<235>
Romar, R.J., (Comp.), and D.E. Baker, Jr., (Comp.), New Mexico State Bureau of Mines and Mineral Resources, Socorro, NM

Selected Papers from 1970 Uranium Symposium at Socorro, New Mexico. New Mexico State Bureau of Mines and Mineral Resources Circular 118; 61 pp. (1971)

> Six papers presented at the symposium are published in this circular. Three papers present aspects of uranium exploration: 1) Uranium exploration in Southwest Texas, 2) Exploration Geology Methods in the Grants Mineral Belt, and 3) Hydrometallurgical Aspects of Mineral Exploration. The remaining three papers explore areas of uranium production: 1) The Beneficiation and Refining of Uranium Concentrates, 2) Production of Uranium Tetrafluoride and Uranium Metal, and 3) Microbiological Leaching of Uranium. (PAG)

Each paper has been abstracted and input separately.

<236>
Rood, R.E., Bendix Field Engineering Corporation, Grand Junction, CO

Preliminary Geologic Investigation of Uranium Favorability in the Red River Valley of North Dakota and Minnesota. GJBX-57(77); 12 pp. (1977, August)

> A study was made of Precambrian through Upper Cretaceous rocks in a 20,000-sq-mi area of eastern North Dakota and western Minnesota to determine their favorability for uranium deposits. The study was confined to a review of literature, maps, and well logs. During most of post-Precambrian time, this area served as a transitional zone between the dominantly positive Canadian Shield to the east and the generally negative Williston basin to the west. Periodically, marine transgressions onto the shield margin resulted in the deposition of over-stepping or onlapping clastic wedges, which in places rest directly on eroded and highly weathered rocks of Precambrian age. Such onlapping units include the Deadwood Formation (Cambrian), the Winnipeg Formation (Ordovician), and the Inyan Kara Group (Cretaceous). There are no known uranium deposits in the project area; but the clastic onlapping units do contain thick, coarse-grained sandstones, varying amounts of organic material, and considerable detrital material from Precambrian crystalline rocks. They are believed to be relatively permeable, very widespread, and are not far from areas of anomalous uranium concentration in Precambrian rocks. It is postulated that uranium derived by weathering of the Precambrian rocks could have been transported westward in detritus or in solution in ground or surface waters. Solutions could have traveled through fractures in crystalline rocks or through permeable clastic rocks and uranium may have precipitated where favorable reducing conditions existed. Evidence of possible uranium favorability includes anomalous uranium concentrations, basic materials, and other evidence of the presence or former presence of uranium. (Auth)

<237>
Ruiz Reyes, J.A., Universidad Nacional Autonoma de Mexico, Facultad de Ingenieria, Mexico

La Exploracion Magnetica Como Guia Para Localizar Uranio. NP-20304; Ph.D. Thesis; 86 pp. (1978)

> In the Mier area the magnetometer method revealed the contrast between the magnetic expression of the favorable horizon and adjacent layers, thus proving that the method has the possibility of detecting zones of oxidation in strata favorable to uranium deposits. The width of the zone of oxidation can be delimited in a fairly approximate way using this method. It is concluded that magnetometry is a good source of aid as a preliminary tool in regional surveys, thus helping radiometry to localize favorable zones in distinct types of lithology, and together with radiometry, can also be a means of delimiting hydrothermal zones which would be favorable for a deposit. Magnetometry can also be utilized when the objectives are placer deposits by locating the placers and focusing the drilling on these spots. (PAG)

<238>
Sachdev, S.C., Gulf Science and Technology Company, Pittsburg, PA

Clay Minerals as Uranium Tracers for Roll Front-Type Deposits. Proceedings of the Joint Annual Meeting of the Geological Association of Canada, the Mineralogical Association of Canada, and the Geological Society of America, Toronto, Ontario, October 23-26, 1978. The Geological Society of America, Boulder, Colorado, (p. 484), 531 pp. (1978)

> The mineralogy of samples from five cores obtained across a uranium roll-front deposit in the Grants Mineral Belt, New Mexico, was determined. The ore body occurs in the Brushy Basin Member (Poison Canyon Sandstone) of the Morrison Formation (Late Jurassic), lies at redox interface in a structural depression, and is confined between fine-grained 'mudstone' rock units. Detailed mineralogical, chemical, and textural data confirm some of the earlier suggestions that these mudstones are, in fact, the altered products of volcanic tuffaceous material. These rocks are composed primarily of montmorillonite clays having tobacco-leaf morphology, and are referred to as 'bentonites' in this paper. The host sandstones contain scattered intercalations of montmorillonitic material in the form of clay galls, stringers, and lenses derived from bentonites. A second-generation authigenic cellular montmorillonite is also identified in the host rocks. Distinction between the two genetically different types of montmorillonites for quantitative purposes was made using scanning electron microscope, x-ray diffraction and size analysis. The cellular montmorillonite is most abundant in the oxidized zone and decreases toward ore and reduced zones. Authigenic chlorite has formed later than, and at the expense of, cellular montmorillonite; it is concentrated in the ore zone. Kaolinite in sandstones is the last clay mineral to form, and is most abundant in the reduced zone. The characteristic authigenic clay-mineral suites of different geochemical zones suggest these to be related to the ore-forming process; their use as uranium-tracers is apparent. (Auth)

<239>
Sainsbury, C.L., T. Hudson, R. Kachadoorian, and
T. Richards, USGS, Washington, DC

Geology, Mineral Deposits, and Geochemical and Radiometric Anomalies, Serpentine Hot Springs Area, Seward Peninsula, Alaska. USGS Bulletin 1312; Contributions to Economic Geology, 1969, (H1-H18), 320 pp. (1969)

During 1968, detailed mapping of the Humbolt Creek and adjacent areas in the Serpentine-Kougarok area was carried out as part of a program that included detailed geochemical studies and airborne geophysical surveys. An airborne magnetic and radiometric survey was made for the USGS by Lockwood, Kessler, and Bartlett, Inc. and several radiometric anomalies were outlined. None of the anomalies were checked in the field, but several factors were considered significant. First, although several broad anomalies within the granite tend to correspond to topographic highs, the area with the highest radiation lies along the southeastern edge of the granite in an area not checked in detail previously. The single uranium deposit known on the Seward Peninsula, at Brooks Mountain, about 80 miles west, consists of secondary uranium minerals that are associated with a lobe of granite. The similarity of geology and location of radiometric anomalies may be significant and recent work has shown the granite in the area may be a late-stage differentiate. Secondly, the radiometric anomaly does not coincide with known mineralized bedrock; hence, no direct correlation can be made between anomalies and ore deposits. And thirdly, all the anomalies occur above the granite or the orthogneiss, which suggests that radioactive accessory minerals may be the principal source of the radiation. The second and third factor tend to lessen the possible importance of the first factor. (JST)

<240>
Shannon, S.S., Jr., Los Alamos Scientific
Laboratory, Los Alamos, NM

Detailed Uranium Hydrogeochemical and Stream Sediment Reconnaissance of the Tallahassee Creek, Badger Creek, Castle Rock Gulch, and Buffalo Gulch Areas in the Northwestern Part of the Pueblo NTMS Quadrangle, Colorado. GJBX-42(79); LA-7593-MS; 109 pp. (1979, February)

A total of 62 water and 620 sediment samples was collected from 626 locations within four areas totaling 400 sq km in the northwestern part of the Pueblo quadrangle, Colorado. Water and sediment were collected from streams and springs at an actual density of one sample location per 0.65 sq km in the Tallahassee Creek, Badger Creek, Castle Rock Gulch, and Buffalo Gulch areas. Only 25 ground-water samples were collected. Mean uranium values for both water and sediment samples are highest for the Tallahassee Creek and Castle Rock Gulch areas. The ten spring samples collected from these two areas contain the highest mean uranium concentrations for both water and sediment and the highest U/Th ratios in sediment. Because the Tallahassee Creek conglomerate and Echo Park alluvium contain uranium orebodies, the association of high uranium content and high U/Th ratios with waters and sediments collected from springs is an indication that ground-water and spring sediments may be the most effective media for the detection of blind ore deposits. Most samples which contain high uranium values in both water and sediment from the Tallahassee Creek and Castle Rock Gulch areas have a provenance from granodiorite of Precambrian X age. The association of high uranium values with high U/Th ratios, especially in the Castle Rock Gulch area, indicate that granodiorite may be a source or even a host rock for uranium. Other units associated with a number of relatively high uranium concentrations in water or sediments are the Echo Park alluvium and the Tallahassee Creek conglomerate in the Tallahassee Creek area and the Badger Creek tuff in the Badger Creek area. High thorium values also are associated with both the Echo Park alluvium and Badger Creek tuff but not with the granodiorite. There may be uranium ore deposits in the Castle Rock Gulch area comparable to those already discovered in the Tallahassee Creek area because their geologic and geochemical settings are similar. High uranium concentrations and high U/Th ratios for sediments derived from granodiorite of Precambrian X age are indications that granodiorite may be an important major source of uranium in the Tallahassee Creek area. If so, the relatively high uranium values and high U/Th ratios might be useful guides to uranium ore in the Castle Rock Gulch area. (PAG)

Field and analytical data for each sample site in the Tallahassee Creek area are given for waters in Appendix A-I and for sediments in Appendix A-II. Similar data for the Badger Creek, Castle Rock Gulch, and Buffalo Gulch areas are given in Appendixes B-I and B-II, C-I and C-II, and D-I and D-II, respectively. Appendixes E-I, E-II, and E-III describe sampling and analytical procedures, codes used in the data listings, and provide a key to sample types in the data listings.

EXPLORATION

<281>
Sharp, R.R., Jr., and D.E. Hill, Los Alamos Scientific Laboratory, Los Alamos, NM

Uranium Hydrogeochemical and Stream Sediment Reconnaissance Data from the Area of the Teller, Bendeleben, Candle and Kateel River Quadrangles, Seward Peninsula and Vicinity, Alaska.
GJBX-85(78): LA-6848-MS; 161 pp. (1978, May)

A total of 2026 natural waters and 2085 bottom sediments were collected from 2209 sample locations (at a nominal density of one location each 23 sq km) on streams and small lakes throughout the Teller, Bendeleben, Candle, and western one-third of the Kateel River NTMS quadrangles, Alaska. Total uranium was measured in the waters by fluorometry and in the sediments and some few waters by delayed-neutron counting. The uranium content of the waters ranged from below the detection limit of 0.02 parts per billion (ppb) to a high of 14.50 ppb, averaging 0.44 ppb, and that of the sediments ranged from a low of 0.2 parts per million (ppb) to a high of 107.4 ppm, averaging 3.93 ppm. The areal distribution of uranium in surface water appears to depend strongly on the following factors: 1) local topography, 2) ground and surface water mobility and mixing, 3) distribution and solubility of uranium in the ground, 4) presence or absence of fault and fracture systems, and 5) water chemistry. Also, it may depend on the type and extent of vegetation and possible evaporative concentration. Ten of the 23 uranium occurrences reported within the area are associated with contoured clusters of water samples which contain relatively high (1-2 ppb) uranium contents. These are all associated with granitic or migmatic rocks. The areal distribution of uranium in sediment appears much more simply related to the geology and known uranium occurrences. Two district-sized areas of increased uranium content in sediment are located in the Bendelben and Candle quadrangles, in and around the Bendeleben and Darby Mountains in the former and around Hunter Creek and Granite Mountain in the latter. These areas are associated with granitic and associated migmatic rocks, radiometric anomalies, and a corresponding increased uranium content in waters. (PAG)

<282>
Sharp, R.R., Jr., and D.E. Hill, Los Alamos Scientific Laboratory, Los Alamos, NM

Uranium Concentrations in Stream Waters and Sediments from Selected Sites in the Eastern Seward Peninsula, Koyukuk, and Charley River Areas, and Across South-Central Alaska.
LA-6689-MS; GJBX-79(78); 43 pp. (1978, April)

During the summer of 1975, 617 water and 648 stream sediment samples from 691 locations, and bedrock samples, were collected from the eastern Seward Peninsula, from north of Koyukuk River, from the Charley River area, and from across south central Alaska. The samples obtained were sent to the Los Alamos Scientific Laboratory (LASL) for analysis of uranium. The report contains the LASL uranium determinations by fluorometric analysis (the water samples) and delayed-neutron counting (the stream sediments) of the 1265 samples. The objective of the report is to make public the standard computer format of the uranium determinations used in NURE Hydrogeochemical and Stream Sediment Reconnaissance reports previously published and open-filed in a Grand Junction Office (Department of Energy) publication - GJBX-28(77). Area uranium concentration overlays are also provided, which provides an explanation of differences between the uranium values for sediment as determined by acid dissolution/extraction/fluorometry and delayed-neutron counting. (RRS)

<283>
Sherrington, G.H., Geopeko Limited, Chatswood, N.S.W. 2067, Australia

Some Aspects of Natural Gamma Radiation in Ore Search. Journal of Geochemical Exploration 8:325-335. (1977)

Natural gamma radiation from the decay chains headed by U-235, U-238, Th-232 and K-40 can be detected and measured by a variety of instruments. Hand-held total count scintillometers indicate a portion of the gross gamma radioactivity. Portable four-channel differential spectrometers allow some discrimination between contributions from the U, Th and K series. Similar discrimination is possible with downhole and airborne gamma-ray spectrometers. Laboratory spectrometers using high-resolution germanium detectors show the contribution of many individual isotopes. The most obvious and widespread use for all of these instruments is in exploration for U deposits. Deposits which are radiometrically simple, such as Ranger 1, Northern Territory, need less complex instrumentation than deposits such as Mary Kathleen, Queensland, which has significant Th-232 series activity. Radiometric complexity is also caused by disequilibrium in the U decay series. Exploration for base metal deposits can also be assisted by gamma spectrometry. The weak radiometric expression can show character attributable to recognizable events (such as K metasomatism) or can give an empirical pattern correlatable with lithology. There is increasing attention being given to airborne gamma surveys as a guide to geological mapping. A current resurgence of interest in natural gamma applications is being assisted by the development of better, more compact instrumentation. (Auth)

<244>
Simov, S.D., International Atomic Energy Agency, Vienna, Austria

Recognition and Evaluation of Uraniferous Areas. Atomic Energy Review 14(1):187-191. (1976, March)

The migration and concentration of uranium depends primarily on its crystal chemistry and those of other elements that built up the earth's crust and provide framework of varying stability but suitable for the accommodation of the mobile uranium atom. Uranium has a cation/anion ratio with oxygen of 0.82, slightly higher than that characteristic for the ideal cubic coordination, typically represented in fluorite and pyrochlore type structures, which are the most favorable for accomodating the U(+4) ion. Hexavalent uranium is the most awkward ion as far as atomic substitution in the crystal structures of minerals is concerned, being invariably found as the uranyl group, UO(+2), with dimensions of 2.64 angstroms X 6.04-6.84 angstroms. Uranium possesses amphoteric or slightly alkaline properties and in both the quadrivalent and the hexavalent state has pronounced tendencies to form complexes with water, organic compounds and anions such as CO3(-2), PO4(-3), AsO4(-3), SiO4(-4), etc. Because of its peculiar crystal chemistry, uranium was concentrated in the earliest rock types, most probably first in a dispersed manner. It is also possible that preliminary concentration of uranium took place in melts subjacent to the primeval earth's crust, and during extrusions or post-extrusive hydrothermal activity this uranium had been appropriately introduced in the already existing rocks. Zirconium and uranium are concentrated in highly alkalic rocks, especially in syenites unsaturated with respect to silica. Zircon may include considerable amounts of uranium in its structure; U(+4) substituting for Zr(+4) in eight-fold co-ordination. The distribution of uranium in bedrock is being used as a guide to the recognition of potential uranium ore areas. This method gives an opportunity for the preliminary evaluation of the uranium-ore favorability of areas, but once a region with high uranium content in rocks is recognized, then more detailed studies must be undertaken to find out the other important features of that area and those adjacent to it, such as tectonic pattern and geochemical environment, which can help in selecting the best district for prospecting. Plate tectonic theory still has not found application in uranium exploration geology, and there is some doubt concerning the application of the theory to identify uranium ore provinces. A good exploration target for uranium is the areas built up by Precambrian rocks. It was reported that about 90 percent of uranium reserves occur in Precambrian rocks or in sediments immediately overlying a Precambrian basement, as in the case of the Colorado-Wyoming province. Favorable locations for uranium mineral formation are uplifted geoblocks within or outside Precambrian platforms that have been subject to thermal reworking. The best example of this is the uranium deposits of the Colorado Plateau, an originally uplifted and thickened geoblock. Areas adjacent to or overlying oil deposits or evaporites are also considered as favorable uranium exploration targets. Uranium deposits related to oil and gas-bearing structures are known in Texas, Wyoming, Utah, New Mexico and Oklahoma. There are often inclusions in minerals containing organic matter, gas, and oil. A very good technique for preliminary evaluation of uranium ore potential of areas is airborne gamma-ray spectrometry. (JST)

<245>
Skidmore, J.H., Union Mines Development Corporation, New York, NY

Preliminary Reconnaissance Survey of Idaho Placer Deposits. RMOO-81; 17 pp. (1944, March)

Seven major and minor Idaho auriferous gravel-bearing areas were examined for uranium. The Burgdorf, Elk City, Idaho City, Pioneerville, Centerville, and Garden Valley districts are indicated as having some uranium mineralization. The Boise Basin area, where black sand concentrates were tested, was found favorable. The investigation showed that uranium is present in insignificant quantities - 10,000 lbs U3O8 is the estimated tonnage for the ten districts. (PAG)

<246>
Soonawala, N.M., McGill University, Department of Mining and Geophysics, Montreal, Quebec, Canada

Data Processing Techniques for the Radon Method of Uranium Exploration. Canadian Mining and Metallurgical Bulletin 67(744):110-116. (1974, April)

Radon-222 is often used as a detecting agent in the exploration for uranium mineralization. Being the only gaseous isotope in the uranium-238 series, radon is endowed with a mobility not associated with the other members. Provided a satisfactory environment exists for its transportation, it can travel over distances larger than the normal gamma-ray range in solid materials, and thus its detection can enable one to detect the presence of mineralization covered with relatively thick overburden. The maximum depth of mineralization which can normally be detected with this method varies between 10 and 50 ft, and is thus a distinct improvement on the few inches possible with the gamma detection technique. The half-life of radon is 3.8 days. As a result of this, significant concentrations of radon cannot be encountered at too large a distance from the source. The radon technique is unique in that it is the only uranium exploration method, with the exception of established geochemical techniques, capable of giving some degree of depth penetration. (JMT)

<247>
Staatz, M.H., C.M. Bunker, and C.A. Bush, USGS, Denver, CO

Geochemical Prospecting for Thorium Veins by Stream-Sediment Sampling, Lemhi Pass Quadrangle, Idaho and Montana. USGS Professional Paper 750-C, Geological Survey Research 1971, (pp. C136-C140). (1971)

In an area that contains many thorium veins, 67 stream-sediment samples were collected to determine whether the thorium content of the samples would aid in locating the veins. The thorium content of most of the samples ranged between 6 and 20 ppm. The results obtained from the geochemical prospecting method were disappointing. Thorium from poorly exposed veins does not tend to collect in the sediments, and the most anomalous sample collected had a thorium concentration only 3 times the average backgroup. The samples that were clearly above average background values came from streams that were a short distance below exposed veins; in two of the samples the stream actually cut across the toe of a mine dump on these veins. Thorium veins which have workings on ridges or which are covered with alluvium where they cross streams furnished only minor amounts of thorium to the stream sediments. (JET)

<248>
Taucher, L.H., Atlantic Richfield Company

Uranium Exploration in Southwest Texas. 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. 3-12), 61 pp. (1971)

Intensive exploration is being conducted along an arcuate band parallel to the Gulf Coast some 50 milies wide and 400 miles long, extending from the Mexican border at the Rio Grande River northeastward to the Trinity River north of Houston. The method of entrapment of uranium deposits in SW Texas is not fully understood. It is apparent that many accumulations are fault controlled and others appear to be deposited in channel sands. Hydrogen sulfide probably played a leading role in deposition where it was present in small structures and along faults. Reducing environments created in coaly sedimentary sequence probably promoted precipitation of uranium. Exploration methods employed in SW Texas include gamma-ray logging of wildcat, development and work over wells, water sampling, radon sampling, airborne radiometrics, photogeology, and other prospecting techniques. (PAG)

<249>
Thompson, D.T., Gulf Research and Development Company, Pittsburgh, PA

Geophysical Experiments at the Mariano Lake Uranium Orebody. AAPG Bulletin 63(4):695. (1979, April)

Several geophysical experiments were performed over the Mariano Lake orebody before mining began, including surface self-potential methods, surface-to-hole induced-polarization methods, and reflection seismic methods. These geophysical techniques are interesting from an exploration point of view, and they also provide some data which relate to our conceptual model of this orebody. Currents generated in the productive formation by oxidation-reduction reactions do not generate measurable potential anomalies at the surface. Surface-to-hole induced-polarization measurements appear to be capable of detecting an oxidation-reduction front in the vicinity of an exploration borehole. Reflection seismic techniques can provide information concerning the paleostructure of the area. (Auth)

<250>
Tolmie, R.W., Atomic Energy of Canada Limited, Ottawa, Ontario, Canada

Mobile Equipment for Combined Neutron Activation and X-Ray Fluorescence Analysis. CONF-691229; Nuclear Techniques for Mineral Exploration and Exploitation, Proceedings of a Panel, Krakow, Poland, December 8-12, 1969. International Atomic Energy Agency, Vienna, Austria, (pp. 7-26), 187 pp. (1971)

Thermal neutron activation analysis and X-ray fluorescence analysis are practical, complementary techniques for analyzing mineral samples. By one or the other of these techniques most of the elements having atomic numbers greater than 8 can be analyzed, with sensitivity limits that are determined by interelement interferences in most cases. Radioisotope sources can be used to excite the radiations and, if it is necessary to measure silicon which is an important constituent of most rocks, a small radioisotope fast neutron source can be added to the system. Although each of the three means of excitation generally requires that a different kind of detection be used, the remainder of the system, comprising the data accumulation and computation facilities, can be shared. A mobile facility is described in which the data-handling facilities incorporate a small computer. Some details of the analytical techniques employed and the results obtained are given with brief comments on the economics of using such a facility in mineral resources exploitations. (Auth)

<251>
Trexler, P.K., Los Alamos Scientific Laboratory, Los Alamos, NM

Uranium Hydrogeochemical and Stream Sediment Reconnaissance of the Cheyenne NTMS Quadrangle, Wyoming. GJBX-106(78); LA-2737-MS; 67 pp. (1978, June)

From 1499 locations in the Cheyenne quadrangle, 1138 water and 633 sediment samples were collected and analyzed for total uranium. The uranium concentration in waters ranged from 0.01 to 296.30 ppb, with a median of 3.19 ppb and a mean of 9.38 ppb. The uranium in sediments ranged from 0.9 to 93.0 ppm with a median of 3.8 ppm and a mean of 4.5 ppm. Twenty-three water samples above 54.50 ppb and twelve sediment samples above 14.0 ppm were considered anomalous. High uranium concentrations were detected in waters from the northeast corner of the Cheyenne quadrangle. Most wells in this area penetrate aquifers in the carboniferous Cretaceous Lance formation. Some deeper wells in the area may penetrate aquifers in the Wind River formation, which is known to be uraniferous in other parts of Wyoming. High uranium concentrations were detected in sediments from locations in the southern and central Laramie Mountains and along the southeast and east-central edges of the study area. (PAG)

<252>
Updegraff, D.M., University of Denver, Denver Research Institute, Denver, CO

The Relationship of Microorganisms to Uranium Deposits. AEC Research Contract Report AT(05-1)-932; 73 pp. (1969, May 11)

Microbiological studies were carried out on 63 samples of uranium ore and associated sediments collected from three different areas: Grants, New Mexico; Gas Hills, Wyoming; and Travan Area, Colorado. Some of the samples from each area were high grade uranium ore, and others were barren sediments collected nearby. The samples from Grants and Gas Hills were subjected to qualitative microbiological studies in 13 different kinds of culture media under both stationary and agitated aerobic conditions. Cultures were also made in three different culture media and incubated anaerobically. In an attempt to isolate all possible kinds of microorganisms present, media included nutrient broth, casamino acids-glucose media, glucose-salts media, several kinds of FERROBACILLUS and THIOBACILLUS media and Czapek's medium for fungi. Each medium was incubated at 26, 30, 37 and 45 degrees C. The samples from the Travan area were worked up by direct plating of dilutions in order to obtain quantitative counts, and pure cultures were isolated and studied as before. A total of more than 598 cultures was isolated and studied. The conclusions from these studies may be summarized as follows: (1) The samples contained remarkably few microorganisms, as well as very few different kinds of microorganisms compared to what would be found in surface soil samples. (2) Some samples contained no detectable microorganisms at all in a 1 gram sample. (3) Seventy-two percent of the pure cultures isolated belonged to the genus ARTHROBACTER. Other bacterial genera identified were BACILLUS and STREPTOMYCES. No obligate or facultative anaerobes were found. FERROBACILLUS and THIOBACILLUS were not found. Fungi were found in occasional samples only. The most abundant genus was PENICILLIUM. (4) There was no significant difference in flora between samples high in uranium and those low in uranium. (5) There is no indication from these studies that microorganisms can be used as a geomicrobiological prospecting tool for uranium, but it is likely that microorganisms had a good deal to do with the original migration and deposition of uranium.
(Auth) (JRT)

<253>
Van Eeckhout, E.M., R.G. Warren, and D.E. Hill, Los Alamos Scientific Laboratory, Los Alamos, NM

Uranium Hydrogeochemical and Stream Sediment Reconnaissance of the Medfra and Mt. McKinley NTMS Quadrangles, Alaska, Including Concentrations of Forty-Three Additional Elements. GJBX-30(79); LA-7351-MS; 210 pp. (1979, February)

Each of the 1278 water samples was analyzed for 13 elements, including uranium and each of the 1216 sediment samples was analyzed for 43 elements, including uranium and thorium. Uranium values in water samples from the combined Medfra and Mt. McKinley quadrangles ranged from below the detection limit of 0.02 ppb to 8.11 ppb, with a mean of 0.31 ppb. Generally, pond waters have substantially lower uranium contents than stream waters. Relatively high uranium concentrations in water are associated with four reconnaissance airborne radiometric anomalies reported for the Mt. McKinley quadrangle (the Medfra quadrangle had not yet been reported upon). Uranium valued in sediment samples ranged from 0.75 ppm to 33.32 ppm, with a mean of 2.89 ppm. Generally, the uranium contents of pond sediments are substantially lower than those of stream sediments; this may be due to dilution of the inorganic component in a large fraction of pond sediments by highly organic-rich material. Three areas of high uranium concentrations in sediment are associated with geologic features which indicate potential uranium mineralization. These areas are in granitic rocks of the Sunshine Hills and in Paleozoic metamorphic rocks marginal to the Kantishna Hills mining district and to the exposures of the Mt. Foraker granodiorite in the Alaska Range.
(Auth) (PAG)

All field and analytical data are listed in the appendixes; only uranium data are discussed in this report. Appendix I - Listings of Field Data and Elemental Concentrations for Samples from the Mt. McKinley quadrangle, Appendix II - Listings of Field Data and Elemental Concentrations for Samples from the Medfra quadrangle, Appendix III - Listings of Dissolved Oxygen in Waters from the Medfra and Mt. McKinley quadrangles, Appendix IV - Histograms and Statistical Data for Uranium Concentrations in All Water and All Sediment Samples from the Medfra and Mt. McKinley quadrangles, Appendix V - Histograms and Statistical Data for Thorium Concentrations in All Sediment Samples from the Medfra and Mt. McKinley quadrangles, Appendix VI - Standard Procedures, Codes, and Keys

<254>
VanAlstine, C.L., and D.L. Curry, AEC, Casper, WY

The Economics of Mining Uranium in Wyoming Sandstones. Wyoming Sandstone, R.L. Enyert (Ed.), Proceedings of the 22th Field Conference, 1970. Wyoming Geological Association, Casper, WY, (pp. 45-50), 292 pp. (1970)

Uranium mining has been significant in Wyoming sandstone since the 1950's. The outlook is for continued important production for years to come. The principal known uranium deposits occur as rolls in sands of early Eocene, Paleocene, and Early Cretaceous age in districts such as the Gas Hills, Shirley Basin, Crooks Gap, Powder River Basin, and Northern Black Hills. The chief mining method has been the open-pit, although underground mining is likely to become increasingly important with discovery of progressively deeper deposits. Open-pit mining has definite advantages over underground mining, chief of which are lower costs and higher realization of ore reserves. However, stripping has a practicable depth limitation, presently about 400 feet, below which underground mining is usually less costly. The increase during the last decade of geological knowledge regarding the occurrence of roll-ore bodies in Wyoming has resulted in improvements in mining techniques, and has been especially helpful in exploring for, discovering, and eventually mining small ore rolls that might once have been left behind by underground mining operations. Minor uranium production has been obtained from in-situ leaching in the Shirley Basin district of Wyoming, but the process has not yet become competitive with conventional methods as an important mining method.
(Auth) (NBW)

<255>
Wagoner, J.L., Lawrence Livermore Laboratory, Livermore, CA

Hydrogeochemical and Stream Sediment Reconnaissance Basic Data Report for Millett NTMS Quadrangle, Nevada. GJBX-39(79); UCRL-52641; 79 pp. (1978, December)

Wet and dry sediment samples, and water samples at available streams, springs, and wells were collected and analyzed for uranium by delayed neutron counting. Samples were divided into nine general rock types, according to the source rock from which the sediment was derived. The acidic volcanics and Teritary clastics have the highest background uranium concentrations. Western assemblage sediments have moderate background uranium. Eastern assemblage sediments have the lowest background uranium concentrations. Uranium correlates best with the rare earths, hafnium, and thorium in most of the samples, suggesting that uranium exists predominantly in the resistate phase. Uranium is the best indicator of uranium mineralization. Water samples are best for identifying areas of known uranium mineralization, suggesting that the uranium is readily leachable in the deposits. Sediment samples containing the highest uranium concentrations occur near Tertiary rhyolite flows and silicic ash-flow tuff. Water samples having the highest uranium concentration are located near intrusive-metasedimentary contacts in the Toiyabe Range. Th/U ratios are used to differentiate anomalous and background uranium concentrations. Anomalous low Th/U ratios with greater than 5.0 ppm uranium are located near Tertiary silicic volcanics and near the Jurassic Austin Pluton in the Toiyabe Range. (PAG)

Appendix A - Data Organization and Definitions, Appendix B - Numerical Results of Reconnaissance Survey

<256>
Warren, R.G., D.E. Hill, and F.R. Sharp, Jr., Los Alamos Scientific Laboratory, Los Alamos, NM

Uranium Hydrogeochemical and Stream Sediment Reconnaissance Data from the Area of the Shishmaref, Kotzebue, Selawik and Shungnak Quadrangles, Northern Seward Peninsula and Vicinity, Alaska. GJBX-86(78); LA-6885-MS; 94 pp. (1978, May)

From 1356 streams and small lakes or ponds within the Shishmaref, Kotzebue, Selawik, and western portion of the Shungnak NTMS quadrangles in western Alaska 1336 water and 1251 sediment samples were collected. Both a water and sediment sample were generally obtained from each location at a nominal location density of one per 23 sq km. Total uranium was measured in waters by fluorometry and in sediments and some few waters by delayed neutron counting. Uranium concentrations in waters have a mean of 0.31 ppb and a maximum of 9.23 ppb, and sediments exhibit a mean of 3.44 ppm and a maximum of 37.7 ppm. A large number of high-uranium concentrations occur in both water and sediment samples collected in the Selawik Hills, an area underlain by a large silicic pluton of the Hogatza alkaline series. At least two locations within the Selawik Hills appear favorable for further investigation of possible uranium mineralization. Also, a cluster of high-uranium sediments is seen in the Waring Mountains. These sediments are probably derived from a lower Cretaceous conglomerate unit which is associated with known airborne radiometric anomalies. Apparently less favorable areas for further investigation of possible uranium mineralization are also located in the Waring Mountains and Kiana Hills. (Auth) (PAG)

<257>
Warren, R.G., and H.P. Nunes, Los Alamos Scientific Laboratory, Los Alamos, NM

Uranium Hydrogeochemical and Stream Sediment Reconnaissance Data Release for the New Mexico Portions of the Hobbs and Brownfield NTMS Quadrangles, New Mexico/Texas. GJBX-103(78); LA-7182-MS; 61 pp. (1978, June)

A total of 1084 water and 914 sediment samples were collected from 1926 locations within the New Mexico portions of the Hobbs and Brownfield quadrangles. The area lies within the Great Plains geologic province and is characterized by nearly flatlying, undeformed strata. The Llano Estacado is a caliche-cemented surface developed on the Ogalla formation of late Miocene and Pliocene age. The Ogalla formation is about 30-60 m thick and generally overlies the Triassic Dockum group; the latter consists of red mudstone and channel sandstone. Major petroleum production occurs from sandstones in the Permian section. Thick Permian evaporite deposits are mined commercially in the Carlsbad Potash District in the southwestern part of the area. At least four known uranium occurrences are associated with sandstone of the Dockum group; however, there has been no metallic mineral production within the area. The uranium concentrations in waters approximate a lognormal distribution with a mean of 4.73 ppb. The highest uranium concentration was 139.7 ppb. The water samples having the highest uranium content are from wells and ponds in the western and northwestern portion of the Brownfield quadrangle. Most waters containing greater than 20 ppb uranium were collected from areas in which the Dockum group underlies a thin veneer of surficial deposits, near the edge of the caprock, or from saline ponds. The uranium concentrations in sediments approximate a normal distribution with mean of 2.18 ppm for the 914 sediment samples. The highest uranium value found in a sediment sample is 19.3 ppm. A cluster of seven sediments containing more than 3.0 ppm uranium is centered at 33 degrees 34 minutes N, 103 degrees 53 minutes W, where a uranium occurrence is reported at the Hoffacker test hole in the middle of the Dockum group. (PAG)

<258>
Weaver, T.A., W.A. Morris, and P.K. Trexler, Los Alamos Scientific Laboratory, Los Alamos, NM

Uranium Hydrogeochemical and Stream Sediment Reconnaissance of the Rawlins NTMS Quadrangle, Wyoming. LA-7179-MS; GJBX-81(78); 73 pp. (1978, April)

During the spring and winter of 1976 and January and June of 1977, 570 natural water and 1281 waterborne sediment samples were collected from 1369 locations in the Rawlins, Wyoming, NTMS quadrangle. The samples obtained were analyzed at the Los Alamos Scientific Laboratory for total uranium. The uranium concentrations in waters ranged from less than 0.2 ppb to 448 ppb. The mean value was 6 ppb. The concentrations in sediments ranged from 1.2 ppm to 60.8 ppm, with a mean value of 4.1 ppm. Based on simple statistical analyses of these data, arbitrary anomaly thresholds were set at 50 ppb for water samples and 9 ppm for sediment samples. As a result, eleven water and 44 sediment samples were considered anomalous; 1 anomalous water and 25 anomalous sediments could be associated with four of the five major uranium occurrences in the quad. Only the Ketchum Buttes area did not show up in the data. Twelve minor reported occurrences could not be identified by the data. Eleven anomalous samples (8 water and 3 sediment) and 13 near-anomalous samples (10 water and 3 sediment) outline a broad area in the northeast corner of the quadrangle (the drainage area of the Medicine Bow River) where two airborne radiometric anomalies were discovered in an earlier study. (Auth)(MBW)

<259>
Wenrich-Verbeek, K.J., USGS, Denver, CO

Uranium and Coexisting Element Behaviour in Surface Waters and Associated Sediments with Varied Sampling Techniques used for Uranium Exploration. Journal of Geochemical Exploration 8:337-355. (1977)

Optimum sampling methods in surface water and associated sediments for use in uranium exploration are being studied at thirty sites in Colorado, New Mexico, Arizona and Utah. For water samples, filtering is recommended to increase sample homogeneity and reproducibility because for most elements studied water samples which were allowed to remain unfiltered until time of analysis contained higher concentrations than field-filtered samples of the same waters. Acidification of unfiltered samples resulted in still higher concentrations. This is predominantly because of leaching of the elements from the suspended fraction. U in water correlates directly with Ca, Mg, Na, K, Ba, B, Li and As. In stream sediments, U and other trace elements are concentrated in the finer size fractions. Accordingly, in prospecting, grain size fractions less than 90 micrometers (170 mesh) should be analyzed for U. A greater number of elements (21) show a significant positive correlation with U in stream sediments than in water. Results have revealed that anomalous concentrations of U found in water may not be detected in associated sediments and vice versa. Hence, sampling of both surface water and coexisting sediment is strongly recommended. (Auth)

<260>
West, J.P., Union Mines Development Corporation, New York, NY

Report on the Southern Black Hills Mineral Area, South Dakota. RMOO-122; 69 pp. (1944, June 19)

The mineral deposits of the Southern Black Hills include a large number of pegmatites and a few gold deposits and lead-silver deposits. Sixty-eight pegmatites, one pyritic deposit, and two feldspar grinding plants were examined and reported on in the area. Of this number 7 pegmatites were found to contain uranium minerals in small quantities. The best prospect for uranium examined is the Bob Ingersoll mine which is estimated to contain between 500 and 2,000 pounds of recoverable U308. In all of the other 6 pegmatites in which uranium minerals found, the exposures indicate only a few pounds of recoverable U308. Hence the uranium reserves of the area are practically limited to these of the Bob Ingersoll mine, which are too small to warrant any special installation for their recovery. (Auth)(PAG)

Appendix A contains detailed descriptions of properties examined. Appendix B contains a list of samples, assays, and mineral identification. Appendix C contains mineral identifications by D'Arcy George of the New York Office.

<261>
West, J.P., Union Mines Development Corporation, New York, NY

Report on the Northern Black Hills Mineral Area, South Dakota. RMOO-123; 59 pp. (1944, March 20)

Twenty-six mines in the gold and silver mineralized area of the Northern Black Hills were examined for uranium minerals. Autunite and torbernite specimens have been contributed from this area in the past. Uranium minerals occur as rare accessory minerals in a few gold-silver replacement deposits, both in the primary ore and in the oxidized zone. It was concluded that no recoverable quantities of uranium could be produced from the area at that time and no further work should be done in the area. (PAG)

Appendix A contains a list of samples and assays. Appendix B containd detailed descriptions of properties examined.

EXPLORATION

<262>
Winchester, J.W., University of Michigan, Department of Meteorology and Oceanography, Ann Arbor, MI

Activation Analysis in Mineral Prospecting. CONF-691229; Nuclear Techniques for Mineral Exploration and Exploitation, Proceedings of a Panel, Krakow, Poland, December 8-12, 1969. International Atomic Energy Agency, Vienna, Austria, (pp. 1-6), 187 pp. (1971)

Neutron activation analysis has earned a reputation as being one of the most sensitive and reliable methods for trace element determination in a wide variety of materials. In geologic applications, activation analysis is now the method of choice for obtaining high-quality analytical data for trace element composition of rocks and minerals. In this paper some of the current techniques of activation analysis are reviewed and some comments on the selection of geochemical problems relevant to mineral prospecting are presented. (JMT)

<263>
Zietz, I., B.C. Hearn, Jr., M.W. Higgins, G.D. Robinson, and D.A. Swanson, USGS, Washington, DC

Interpretation of an Aeromagnetic Strip Across the Northwestern United States. Geological Society of America Bulletin 82:3347-3372. (1971)

This report discusses the results of an aeromagnetic survey bounded by latitudes 45 degrees 30 minutes N. and 47 degrees N., and extending from the Rocky Mountains to approximately 120 miles offshore in the Pacific Ocean. East of the Rocky Mountains, a larger area has been surveyed in the Great Plains, bounded approximately by latitudes 44 degrees 50 minutes N. and 48 degrees 10 minutes N. and by longitudes 104 degrees W. and 110 degrees W. Throughout the area of the survey, the magnetic map is marked by conspicuous northeast and northwest anomaly trends, lineaments, and breaks in the anomaly pattern. Their regional distribution, over-all magnetic character, and geologic evidence suggest that they are major structural features in the basement rocks. The close correspondence of structural and geologic features in younger rocks with these basement magnetic and structural trends suggest that basement trends controlled or at least greatly influenced intrusion, deposition, and structural history of younger rocks. In some cases, evidence suggests that basement structures have been reactivated during later tectonic activity. Perhaps even more striking than the northeast- and northwest-trending features are large east-west magnetic discontinuities which, in some cases, extend completely across the strip to the edge of the shelf, and which, in some cases, can be correlated with large-scale discontinuities dating back to the Precambrian. (Auth)

Cited as a reference in NURE Contractor Reports.

MINERALOGY

<264>
Axelrod, J.M., F.S. Grimaldi, C. Milton, and K.J. Murata, USGS, Washington, DC

The Uranium Minerals from the Hillside Mine, Yavapai County, Arizona. The American Mineralogist 36(1):1-21. (1951, January)

A small deposit of uranium minerals was found as coatings on gypsum on the 300-foot level of the Hillside Mine in Yavapai County, Arizona. The deposit was made up of schroeckingerite along with several previously unknown minerals that have been named andersonite, swartzite, and bayleyite. These new species are, respectively, hydrous uranyl carbonates of sodium and calcium, of calcium and magnesium, and of magnesium, all of general formula $[X4UO2(CO3)3nH2O]$ where X4 represents respectively Na2Ca, CaMg, and Mg2, and n, respectively, 6, 12, and 18. Analyses, optical data, x-ray patterns, and crystallographic data of these new species are given, with x-ray patterns of two naturally occurring dehydration products for bayleyite and swartzite. (JHT)

<265>
Barczak, V.J., Kerr-McGee Oil Industries, Inc., Oklahoma City, OK

Schroeckingerite from Ambrosia Lake Uranium District. The American Mineralogist 51(5-6):929-930. (1966, May)

Schroeckingerite was found in the Kerr-McGee section 22 mine in McKinley County, New Mexico. The samples were encrustations on sandstone from a mine wall, with gypsum being the predominant mineral with lesser amounts of andersonite and schroeckingerite. Another sample that formed on the metallic chief of a light bulb contained the minor amounts of a zippeite-like mineral in addition to the above minerals. The schroeckingerite described occurred as poorly developed crystals, typically around 10 microns in diameter, intimately mixed with the other minerals. Indices of refraction in white light are alpha=1.492 and gamma-1.540. (JHT)

<266>
Bowles, C.G., USGS, Denver, CO

Economic Implications of a New Hypothesis of Origin of Uranium- and Copper-Bearing Breccia Pipes, Grand Canyon, Arizona. USGS Circular 753: Short Papers of the US Geological Survey Uranium-Thorium Symposium, 1977, J.A. Campbell (Ed.), (pp. 25-27), 75 pp. (1977)

Uranium and copper ores have been mined in the Grand Canyon from breccia pipes developed within Mississippian to Permian formations, including the Redwall Limestone (Mississippian), Supai Group (Pennsylvanian and Lower Permian), and Hermit Shale (Lower Permian); weak mineralization occurs as well in the upper part of pipes within the lower Permian Coconino Sandstone, Toroweap Formation and Kaibab Limestone. Some breccia pipes formed during Mesozoic time, but collapse may have begun as early as Late Permian time. Other pipes apparently were formed during erosion of the Grand Canyon and may be no older than middle to late Cenozoic. Recurrent collapse has also occurred in the older breccia pipes. The breccia pipes in the Grand Canyon are generally believed to be either cryptovolcanic structures or collapse structures formed by solution of limestone by hydrothermal waters. Copper and uranium deposits in these structures are attributed to hydrothermal mineralizing solutions. The author, however, proposes that formation of the breccia pipes and primary mineralization resulted from low-temperature hypogene solutions that consisted either dominantly or entirely of artesian ground water, with secondary enrichment, either by supergene or mesogene solutions, causing the metals to be concentrated in medium- to high-grade orebodies. Canyon cycles of erosion strongly influenced or controlled the secondary enrichment. The typical mineralized pipe developed in four stages: (1) initial solution and collapse in the Redwall Limestone; (2) stopping into the overlying Supai Group and alteration by bleaching and carbonate cementation; (3) continued stoping and primary mineralization, consisting predominantly of pyrite, chalcocite, and uraninite; and (4) secondary enrichment. Limestone solution and collapse within the Redwall Limestone began during the Mesozoic when tilting of the Colorado Plateau permitted ground water to recharge the Redwall. During the second stage, dissolution of the Redwall extended the collapse structure into the Supai. Ground water probably contained dissolved hydrogen sulfide, bisulfide, and sulfide ions, as well as organic carbon and dissolved carbon dioxide. Primary mineralization of the pipe marked the beginning of the third stage. Ground water carrying high valence copper and uranium ions then entered the pipe in the Supai causing the iron, copper, and uranium ions to be reduced, and pyrite, chalcocite, and uraninite were precipitated in the pipe above the point of recharge by aquifers in the Supai. The commencement of Grand Canyon erosion initiated the fourth stage, in which secondary enrichment of uranium and copper in a supergene or mesogene environment was accompanied by renewed collapse in the breccia pipe. Damming of the Colorado River by lava flow in the western part of the canyon during the late Pliocene (?) may have contributed to the supergene development of the ores by reestablishing water tables at or below the extensive erosional surface. (JHT)

<267>
Bowyer, B., AEC, Washington, DC

Yellow Chief Uranium Mine, Juab County, Utah. Guidebook to the Geology of Utah, No. 17, (pp. 15-22). (1963)

The Yellow Chief Mine is located in central Juab County, Utah. Uranium ore was discovered there in 1953, and open pit mining began in 1959 by the Topaz Uranium Company. The host rock of the orebody is composed of a heterogeneous assemblage of poorly indurated fluvial material derived primarily from the erosion of older Tertiary volcanic rocks and secondarily from the erosion of carbonate and quartzite rocks of probable Paleozoic age. This assemblage has been classified as a massive, poorly sorted, conglomeratic, tuffaceous sandstone with a thickness of approximately 120 feet at the mine. The host rock is underlain by a water-laid tuff and by a bentonitic tuff. The mine is located on the north flank of a west- to southwest-plunging anticline. Stratigraphic relationships indicate the folded host rock has been faulted down at least several hundred feet relative to the older, adjacent volcanic rocks. The Yellow Chief mine ranks with those containing over 100,000 tons of ore. The grade of the ore is erratic and varies from ore body to ore body, as well as laterally and vertically within a single ore body. Beta-uranophane [$Ca(UO_2)_2(SiO_3)_2(OH)_2(H_2O)_5$] is the only known uranium mineral in the zone. It fills pore spaces in the sandstone and conglomerate and coats individual particles. Weeksite, a potassium uranyl silicate, occurs in a limestone conglomerate overlying the host rock, and shroeckingerite has been noted in veinlets in a nearby pit. The ore is in numerous lenticular layers confined to a block of the host rock over 2,000 feet long and 500 feet wide. The block is limited on its northwest and southeast sides by faults. The source of the uranium deposit has been suggested to be the uraniferous fluorspar at nearby Spor Mountain. It is believed that the Yellow Chief deposit was formed either by: (1) the erosion of uraniferous fluorspar bodies and the subsequent concentration of the uranium by vadose and ground waters in the permeable host rock, or (2) fluids rich in fluorine, uranium, and perhaps beryllium, which rose along fractures and faults from a magmatic source and deposited their uranium content in the host rock, probably as coffinite or uraninite, which later was altered to beta-uranophane. (JHT)

Cited as a reference in NURE Contractor Reports.

<268>
Brooker, E.J., and E.W. Nuffield, Canada Geological Survey, Ottawa, Ontario, Canada; University of Toronto, Toronto, Ontario, Canada

Studies of Radioactive Compounds: IV-Pitchblende from Lake Athabaska, Canada. The American Mineralogist 37(5-6):363-385. (1952, May)

Six specimens of pitchblende from the Lake Athabaska region of Canada were analyzed for their tetravalent and hexavalent uranium content and x-ray powder photographs were obtained before and after heat treatments. The cell edges of the pitchblende ranged continuously from 5.470 to 5.395 angstroms. The decrease was due to oxygen entering interstital positions in the UO_2 structure with a consequent change of tetravalent uranium to the smaller hexavalent uranium ion. The lowest cell edge represents a composition of near $UO_{2.6}$; the solid solution range of laboratory prepared cubic oxides ceases at about $UO_{2.2-2.3}$. Oxidation is not uniform throughout a pitchblende specimen and this together with a reduction in grain size results in low definition in the powder pattern. The term metamict is not applicable in this connection. The cell dimensions of U_3O_8 increase as oxygen enters the structure. (Auth)

<269>
Butler, J.R., and R. Hall, Imperial College, Department of Geology, Pure Geochemistry Section, London, England

Chemical Characteristics of Davidite. Economic Geology 55(7):1541-1550. (1960, November)

Twelve davidites from several localities and of different parageneses were analyzed for uranium and individual rare earths. Davidite is a titanate of iron with rare earth elements and uranium as essential constituents, and vanadium and chromium as common accessory constituents. The abundance of the total lanthanons exceeded that of yttrium, and the distribution of the individual lanthanons was similar for all specimens analyzed. Both the heavy and light lanthanons were more abundant than the medium lanthanons. Lanthanum generally exceeded cerium and it can exceed the sum of the remaining lanthanons. (Auth)(JHT)

<270>
Chase, A.B., and J.A. Osmer, Aerospace Corporation, El Segundo, CA

Synthesis of Thorianite Crystals from Bismuth Oxide-Lead Fluoride Melts. The American Mineralogist 49(10):1469-1471. (1964)

The growth of large thorianite crystals by long continued fusion of ThO_2 is discussed. ThO_2 crystals can be readily synthesized from $PbO-PbF_2$, $Bi_2O_3-PbF_2$, and PbF_2 flux systems. The melts from which the largest ThO_2 crystals were grown contained 7 mole per cent ThO_2, 15 mole per cent Bi_2O_3, and 78 mole per cent PbF_2. Melts containing 10 mole per cent ThO_2 and 90 percent PbF_2 also produced large crystals. The crystals obtained from a typical melt ranged from 2 to 6 mm, with the largest crystals occurring on the bottom of the crucible. The crystals also occurred on the top surface of the melt and attached to the walls of the crucible. Typically, the crystals were subhedral with (100) being the dominant habit. Microscopic examination revealed the outline of dendrites within some of the crystals. The arms of the dendrites extended along (111) directions. The material outlining the dendrites is finely divided and appears to be flux that was trapped during growth. The crystals are usually colorless and appear to be of good optical quality. It has been found that crystals grown by this technique are easily doped with the rare earth sesquioxides and UO_2. (JHT)

<271>
Chernikov, A.A., G.A. Sidorenko, and A.A. Valuyeva

New Data on Uranyl Minerals in the Ursilite-Weeksite Group. International Geology Review 20(11):1347-1356. (1978, November)

The uranyl silicates include a large group of minerals in which the U/Si ratio is less than one. Included in this group are ursilite, calcium ursilite, magnesium ursilite, gastunite, ranquilite, parafan, haiweeite, and weeksite. The three ursilites are formed in the final oxidation stages of uranium ore, with calcium ursilite being the most common, since it occurs in the oxidation zone of granites, quartz porphyries and limestones. Ursilite and magnesium ursilite has been found only in the oxidation zone of a quartz porphry. Weeksite and haiweeite have also been found in very restricted amounts in granites and quartz porphyries, as well as in Quaternary drifts. Gastunite has not been found in the Soviet Union, but the mineral does occur in Arizona and Texas as radiate-fibrous aggregates in chalcedony and in cavities in tuff-lavas, as well as in the form of pseudomorphs after uraninite in close association with sulfenite, vanadinite, cuprite, limonite, uranophane, and sklodowskite. Ranquilite is similar to one of the calcium ursilite speciments and occurs in Argentina in association with calcite, gypsum, and limonite. (JST)

<272>
Christ, C.L., and J.R. Clark, USGS, Washington, DC

Crystal Chemical Studies of Some Uranyl Oxide Hydrates. The American Mineralogist 45:1026-1061. (1960, September)

Mineralogical and crystal-chemical studies were made of the closely related uranyl oxide hydrates, becquerelite, billietite, fourmarierite, masuyite, schoepite, and vandendriesscheite. Carefully selected single crystals were used to determine accurately the crystallographic constants, the symmetry, and the structural relations of the minerals. The results obtained on the physical properties, the x-ray crystallography, the x-ray powder data, and the optical properties are listed and compared with the work of other investigators in the 23 tables of this paper. (JST)

<273>
Christ, C.L., J.R. Clark, and H.T. Evans, Jr., USGS, Washington, DC

Crystal Structure of Rutherfordine, UO2CO3. Science 121:472-473. (1955, April 1)

Crystals of the mineral rutherfordine, UO2CO3, used in this study were pale yellow to brown and lathlike along [001], with large(100 and somewhat less dominant (010). Clevage parallel to (010) is perfect. Precession and Weissenberg patterns yielded the following data: orthorhombic, space group - Pm2(sub 1)n [C(sub 2v7)] or Pmmn [D(sub 2h13)]; cell contents, 2UO2CO3; a=4.84 plus or minus 0.010 A; b= 9.20 plus or minus 0.008; c=4.29 plus or minus 0.006; density (calculated)=5.74 g/cubic cm. All of the observed reflections obeyed the criterion h+k+l=2n, except a very weak set that appears only on strongly exposed photographs; for this set when h+k=2n, 1=2n+1, and when h+k=2n+1, 1=2n. (JST)

<274>
Cohenour, R.E., Utah Geological and Mineralogical Survey, Salt Lake City, UT

The Beryllium Belt of Western Utah. Guidebook to the Geology of Utah, No. 17, (pp. 4-7). (1963)

The "Beryllium Belt" of western Utah is 15 miles wide and extends 60 miles between the Sheeprock Mountains and the Honeycomb Hills. In the Sheeprock Mountains, beryl is widely disseminated as granules and rosettes within the "white facies" of the Sheeprock granite. Uranium and fluorine minerals are present as thin, non-commercial vein fillings in sheared granite along the south flank of the range. The next beryllium occurrence is in the topaz rhyolite of Topaz Mountain in the southern part of the Thomas Range. Minute crystals of pink beryl are associated with the topaz dispersed in the rhyolite which is of Tertiary age. Non-commercial traces of uranium minerals are present on the east side of the mountain and commercial amounts are found in the Yellow Chief Mine on the east flank of Spor Mountain. The Honeycomb Hills lie on the western end of the belt and contain sparse amounts of beryllium, uranium, and fluorine minerals. The parent mass is principally Tertiary rhyolites, both flows and pyroclastics. Portions of the flow contain an abundance of lithium. (JST)

Cited as a reference in NURE Contractor Reports.

<275>
Cohenour, R.E., Utah Geological and Mineralogical Survey, Salt Lake City, UT

Beryllium and Associated Mineralization in the Sheeprock Mountains. Guidebook to the Geology of Utah, No. 17, (pp. 8-13). (1963)

The Sheeprock Mountains are principally composed of tilted Precambrian and Paleozoic rocks which have been folded and overridden by thrust blocks. The mountain mass was subsequently intruded by monzonite and granite. Beryllium, in the mineral beryl, was first discovered in the Sheeprock granite in the early 1940's. The beryl occurs in thin veinlets and as disseminated particles and nodular replacements in the Sheeprock granite. The beryl-bearing granite is of lighter color than the surrounding granite and is referred to as the "white facies". Associated with the beryl are fluorite, chalcopyrite, pyrite and manganese, and locally, uraninite. (JST)

Cited as a reference in NURE Contractor Reports.

MINERALOGY

<276>
Curtis, L., Urangesellschaft Canada Limited, Toronto, Canada

Uranium in Volcanic and Volcano-Sedimentary Rocks. Proceedings of the Joint Annual Meeting of the Geological Association of Canada, the Mineralogical Association of Canada, and the Geological Society of America, Toronto, Ontario, October 23-26, 1978. The Geological Society of America, Boulder, Colorado, (pp. 384-385), 531 pp. (1978)

Comparative data from deposits and prospects of uranium in volcanics or their volcano-sedimentary derivatives reveal similarities which are attributed to a common genesis. The uranium occurrences have a world-wide distribution and range in age from Proterozoic to Quaternary. They are characterized by the geochemical association of U-F or U-Mo-F and have high U/Th ratios. Above average amounts of Pb, Ba, Zn, Sr, Ti, Zr, and P may also be present. The associated volcanics and tuffs are generally though not exclusively acid in composition. Cogenetic intrusives may contain anomalous amounts of Mo, W, F and Sn. The uranium is also concentrated within fluvial sediments intercalated with the volcanics or subaqueous sediments peripheral to the volcanic centres. Uranium is concentrated in permeable or structurally disrupted zones within these hosts and in some instances has been remobilized and in others concentrated by supergene processes. A wide spectrum of deposits is developed in this environment, ranging from proximal synvolcanic hydrothermal types, to more distal deposits contained within tuffaceous or clastic sediments. The uranium is considered to be of magmatic origin, transported by F and CO2 rich low to moderate temperature hydrothermal fluids which have percolated through the volcanic pile. Additional uranium may have been scavenged during transport of these fluids or during metasomatism. Submarine venting of such fluids may also have provided a source for more distal varieties contained within reducing sedimentary facies. These facies are often rich in sulphur or pyrite and precipitation of uranium may have been influenced by H2S exhalation. The deposits are small, containing 1000 to 10,000 tons U3O8 and although neglected will become increasingly more important as exploration targets. (Auth)

<277>
Deliens, M., Musee Royal de l'Afrique Centrale, Departement de Geologie et de Mineralogie, Tervuren, Belgium

Review of the Hydrated Oxides of U and Pb, with New X-Ray Powder Data. Mineralogical Magazine 41:51-57. (1977, March)

New X-ray powder data are presented for vandendriesscheite, fourmarierite, masuyite, and wolsendorfite. Literature data on the known U-Pb hydrated oxides is reviewed and suitable criteria for their distinction are set forth. (Auth)

<278>
Dymkov, Yu.M., and N.G. Nazarenko

Coffinite and the Nature of Pitchblende Pseudocrystals. Geochemistry 4:348-358. (1962)

Pitchblende pseudocrystals and coffinite from the Rudnyye Mountains were examined by mineralogical and X-ray methods. The pitchblende pseudocrystals were found to be isotopic coffinite or pseudomorphs of pitchblende or "hydronasturan" after coffinite. The possibility of the existence of various intermediate compounds in the uranium oxide-uranium hydroxide-uranium silicate series is considered. (Auth)

<279>
Emerson, D.O., The Pennsylvania State University, Department of Mineralogy, University Park, PA

Secondary Uranium Minerals at the W. Wilson Mine near Clancy, Montana. M.S. Thesis; 73 pp. (1955, June)

Meta-autunite, meta-uranocircite, meta-torbernite, meta-zeunerite, uranophane, beta-uranophane, phosphuranylite, gummite, and an unknown mineral were found in the W. Wilson Mine, near Clancy, Montana. Pitchblende was the primary uranium mineral in the deposit, and it was altered and leached by ground water to form the secondary minerals. The secondary minerals show a distinct zonation about primary uranium concentrations. Compositional variations in the solutions from which these minerals were precipitated, together with the differences in solubility of the secondary minerals is thought to have caused the zonation. No conclusive evidence as to the possible role of supergene enrichment in the secondary uranium deposition could be found, but the apparent limited movement of most of the secondary uranium from a primary uranium source suggest that enrichment by supergene solutions was not a major factor. (JHT)

<280>
Emerson, D.O., and W.D. Wright, The Pennsylvania State University, University Park, PA

Secondary Uranium Minerals at the W. Wilson Mine in the Boulder Batholith, Montana. The American Mineralogist 42:222-239. (1957)

Secondary uranium minerals found in the W. Wilson mine, near Clancy, Montana, include meta-autunite, meta-uranocircite, meta-torbernite, meta-zeunerite, uranophane, beta-uranophane, phosphuranylite, gummite, and an unidentified mineral, possibly a complex uranium silicate. Uraninite in the "siliceous reef" deposit has been leached and altered by ground water to form the secondary minerals. The deposition of autunite and torbernite as the meta-I hydrate, apparently at normal ground water temperatures, would appear to lower the range of temperature stability previously reported for these minerals. Isomorphous substitution among the four minerals of the meta-torbernite group may be responsible for this difference in stability. Although isostructural with uranophane, the W. Wilson material of this composition has minor discrepancies in its optical character which may be due to the extra Ca, Ba, or Pb in the mineral. (Auth)

<281>
Erickson, M.P., University of Utah, Salt Lake City, UT

Volcanic Geology at Western Juab County, Utah. Guidebook to the Geology of Utah, No. 17, (pp. 23-35). (1963)

Volcanic flows, ignimbrite layers, and air-fall pyroclastics of rhyolitic, latitic, andesitic, and Basaltic composition are widely distributed in western Juab County. In four separate areas, eruptive centers can be recognized or inferred and each center appears to have supplied most of the volcanic material in the area in which it is located. The four areas of volcanic rocks are separate, elevated physiographic units, with intervening lower portions of valley fill. They constitute the Thomas Range, the Keg Mountains, the Honeycomb Hills, and Fumerole Butte. Several volcanic units of different ages are found in the region though no one area contains all units. Some units are widespread and others are more localized. In some cases the apparently widespread units may have been erupted contemporaneously from different vents. The volcanic series rest, with marked angular unconformity, on Paleozoic sedimentary rocks. They have not participated in the general folding which affected the Paleozoic and Mesozoic rocks of the region and therefore are post Mesozoic in age. Within the volcanic series there are distinct unconformities which indicate erosion intervals of long duration between some of the units. Inferences based on comparisons with other nearby areas, topographic evidence, and relationships with Quaternary gravels and lake deposits indicate ages of early Tertiary, late Tertiary, and Quaternary for different units of the volcanic series. (JMT)

Cited as a reference in NURE Contractor Reports.

<282>
Fisher, F.G., and F. Meyrowitz, USGS, Washington, DC

Brockite, a New Calcium Thorium Phosphate from the Wet Mountains, Colorado. The American Mineralogist 47:1346-1355. (1962, November)

Brockite, a calcium thorium phosphate mineral from the Wet Mountains of Colorado, is found as massive reddish aggregates and as earth yellow coatings in veins and altered granitic rocks. The mineral is similar in composition to grayite, but it corresponds in hexagonal symmetry to rhabdophane. Brockite is a red-brown to pale yellow, translucent mineral with a greasy luster and a specific gravity of 3.9 plus or minus 0.2. In transmitted light it is moderately birefringent or opaque due to hematite stain, uniaxial (+), with parallel extinction and positive elongation: W=1.680 plus or minus .002; E=1.695 plus or minus .002. The formula is Ca(sub 0.43)Sr(sub 0.03)Ba(sub 0.02)Th(sub 0.41)RE(sub 0.11)[PO4(sub 0.83)(CO3)(sub 0.17)]0.9 H2O; Z=3. An analysis of the rare earth content shows an unusually high proportion of Nd2O3 with respect to CeO2, La2O3, and Y2O3. The low ratio Ce/(La+Nd) of 0.58 is believed to reflect the formation of brockite under oxidizing conditions. The x-ray diffraction pattern is nearly identical to that of rhabdophane; thus distinct from grayite, which is pseudohexagonal. The cell dimensions are a=6.98 angstroms, c=6.40 angstroms, V=270 cubic angstroms. Upon heating brockite acquires a monazite-type structure, with spacings close to those of cheralite. (Auth) (JMT)

<283>
Frondel, C., Harvard University, Cambridge, MA

Mineralogy of Uranium. The American Mineralogist 42(3-4):125-132. (1957, March)

Approximately 70 different minerals are known that contain uranium as an essential constituent. Only a few of these elements are important as ores of the element. Uraninite is the most important ore mineral of uranium. Its ideal chemical composition is uranium dioxide (UO2), but typically variable and often large amounts of hexavalent uranium ions are found in the mineral. Coffinite, a silicate of tetravalent uranium, is widespread in the unoxidized deposits of the Colorado Plateau. It is isostructural with zircon and a member of the nesosilicate group. (JMT)

<284>
Frondel, C., Harvard University, Cambridge, MA

Studies of Uranium Minerals (IX): Saleeite and Novacekite. The American Mineralogist 36:680-686. (1951)

Novacekite, from Schneeberg, Saxony, has the compositon Mg(UO2)2(AsO4)2-nH2O and it probably forms a complete series to the phosphate analogue, saleeite. Analyzed material with As:P approximately 1:1 is tetragonal with a (sub 0)=7.12 angstroms, c(sub 0)=20.14 and gravity of 3.3. Optically this material, like other members of the series, has an anomalous biaxial negative with nX=1.620, nY=nZ=1.637, 2V 0 to 15 degrees; gravity 3.6. An analysis is given of a new occurrence of saleeite, Mg(UO2)2(PO4)2-nH2O, at Mina da Quarta Seira, Sabugal, Portugal; tetragonal with a(sub 0)=7.01 angstrom, c(sub 0)=19.84; biaxial negative with nX=1.565, nY=1.582, nZ=1.585, 2V is approximately 65 degrees and r greater than v. Saleeite from Shinkolobwe, Belgian Congo, has a(sub 0)=7.02 angstrom, c(sub 0)=19.81; nX=1.554, nY=nZ=1.571, 2V 0 to 10 degrees. Novacekite and saleeite closely resemble and are isostructural with fully hydrated autunite. The indices of refraction vary with the content of zeolitic water within the limits of stability of the fully hydrated phase. (Auth) (JMT)

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<285>
Frondel, C., Harvard University, Cambridge, MA; USGS, Washington, DC

Mineral Composition of Gummite. The American Mineralogist 41(7-8):539-568. (1956, July)

The name gummite has been widely used for more than 100 years as a generic term to designate fine-grained yellow to orange-red alteration products of uraninite. A study of about 100 specimens of gummite from world-wide localities was made by x-ray, optical and chemical methods. Almost all of the specimens were identified as already known uranium minerals. Typically, gummite occurs as an alteration product of uraninite crystals in pegmatite. Such specimens usually show a characteristic sequence of alteration products: (1) A central core of black or brownish-black uraninite. (2) A surrounding zone, yellow to orange-red, composed chiefly of hydrated lead uranyl oxides. (3) An outer silicate zone. The second zone constitutes traditional gummite. Chemically the formation of the orange-red gummite zone is characterized by oxidation of tetravalent uranium to hexavalent uranium and hydration. There is usually little or no addition of material other than H_2O at this stage, but leaching of uranium relative to lead may be a factor. The outermost silicate zone is due to reaction of the hydrated oxides of gummite zone with meteoric or possibly hydrothermal waters carrying silica and usually also calcium. The Th and rare earths contained in the original uraninite are usually completely removed during the formation of the silicates. (JNT)

<286>
Frondel, C., Harvard University, Cambridge, MA

Hydroxyl Substitution in Thorite and Zircon. The American Mineralogist 38:1007-1018. (1953)

The thorite-like minerals, thorogummite, nicolayite, hydrothorite, maitlandite, mackintoshite, and hybilite, were found to be minor chemical variants of a single phase, for which the name thorogummite has priority. Thorogummite is isostructural with thorite and has the same unit-cell dimensions. It differs in being secondary in origin, in being formed by the alteration of primary thorium minerals including thorite itself, in occurring as fine-grained aggregates that are not metamict but crystalline, and in containing essential water. Chemically, thorogummite seems to be a hydroxy-containing variant of thorite, $ThSiO_4$, in which there is a serial substitution of $(OH)_4$ for SiO_4 with the formula $Th(SiO_4)_{1-x}(OH)_{4x}$. Crytolite has an analogous relation to zircon. (Auth) (JNT)

<287>
Frondel, C., Harvard University, Cambridge, MA

Studies of Uranium Minerals (V): Phosphuranylite. The American Mineralogist 35:756-763. (1950)

An ill defined uranium mineral, phosphuranylite, until now known only from North Carolina is redescribed from twelve new localities. Phosphuranylite is isostructural with dewindtite, $Pb_3(UO_2)_5(PO_4)_4(OH)_4-10H_2O$, and its ideal formula is presumed to be $Ca_3(UO_2)_5(PO_4)_4(OH)_4-10H_2O$. Analyses show much less calcium than required by this formula. It occurs as dense, golden yellow films composed of microscopic rectangular plates, and is found principally in the weathered zone of pegmatites containing uraninite. Crystallization is tetragonal or orthorhombic. Phosphuranylite is optically negative with somewhat variable indices: nX=1.660 to 1.690 (colorless to pale yellow), nY=1.696 to 1.724 (golden yellow), nZ=1.698 to 1.724 (golden yellow); 2V=0 to 35 degrees. Lead substitutes for calcium in some varieties with accompanying increase in indices of refraction. (Auth) (JNT)

<288>
Frondel, C., Harvard University, Cambridge, MA

Studies of Uranium Minerals (VII): Sabugalite, an Aluminum-Autunite. The American Mineralogist 36:671-679. (1951)

Sabugalite is a member of the autunite group and it has a composition of $HAl(UO_2)_4(PO_4)_4-16H_2O$. It is a secondary mineral found associated with meta-autunite, saleeite, and phosphuranylite. Sabugalite occurs as crusts of yellow platy crystals with perfect cleavage {001}, a hardness of 2 1/2, and a gravity of 3.20. Optically, air dried sabugalite has an anomalous biaxial negative character with nX=1.564-1.565 (colorless), nY=1.581-1.583 (yellow), nZ=1.582-1.584 (yellow), and 2V=0 degrees to moderate. X-ray study indicates a tetragonal cell with a(sub 0)=6.96 angstroms, c(sub 0)=19.3; a (sub 0):c (sub 0)=1:2.773. Sabugalite is isostructural with fully-hydrated autunite, $Ca_2(UO_2)_4(PO_4)_4-16H_2O$, with Al'''+H'=2Ca''. Sabugalite breaks down between 68 and 101 degrees to a new phase which is isostructural with the artificial meta-II hydrate of autunite. The water content of the fully-hydrated and meta-II hydrates of sabugalite varies zeolitically with accompanying variation in the indices of refraction. (JNT)

<289>
Frondel, C., Harvard University, Cambridge, MA

Studies of Uranium Minerals (I): Parsonsite and Randite. The American Mineralogist 35:245-250. (1950)

Parsonite, $Pb_2(UO_2)(PO_4)_2-2H_2O$, from the Ruggles pegmatite of New Hampshire and from Wolsendorf, Bavaria is described. The New Hampshire material occurs as crusts of microscopic monoclinic crystals that are elongated on [001] and flattened on [010], with [001] as the terminal face and beta equalling 99 degrees. The Parsonite is citron-yellow in color, with a hardness of 2 1/2 to 3, a specific gravity of 5.37, and a c(sub 0) of 6.8 angstroms. Analysis gave PbO 47.43, UO_3 34.68, P_2O_5 14.46, and H_2O 3.43 for a total of 100.00 after the deduction of 5.64 percent quartz. The indices of refraction vary with the water content; most crystals having nX of about 1.870, nZ of approximately 1.890, and an angle of extinction of approximatley 19 degrees. Randite, originally described from Philadelphia, Pennsylvania, in 1978 as a carbonate of calcium and uranium is discredited as a mixture consisting principally of calcite and beta-uranotile with some tyuyamunite. (JNT)

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<290>
Frondel, C., Harvard University, Cambridge, MA

Studies of Uranium Minerals (X): Uranopilite. The American Mineralogist 37:950-959. (1952)

The status of a number of natural uranium sulfates that have been reported in the literature is reviewed. Of the nineteen different names given as species or generic designations for uranium sulfates, only three (johannite, zippeite, and uranopilite) can be adequately defined on the basis of existing data. Of the remaining sixteen reported uranium sulfates (Alpha-uranopilite, Basisches Schwefelsaures Uranoxyd, Basisches Uransulphat, Beta-uranopilite, Calciouranoconite, Cuprozippeite, Dauberite, Medjidite, Uraconise, Uraconite, Uranbluthe, Urangrun, Uranochalcite, Uranocker, Uranvitriol, and Voglianite) little is known and many were set forth as distinct species on the basis of chemical analysis which were made by faulty analytical procedures, or which were made on mixtures. (JMT)

<291>
Frondel, C., and F. Cuttitta, Harvard University, Cambridge, MA; USGS, Washington, DC

Studies of Uranium Minerals (XIV): Renardite. The American Mineralogist 39:448-451. (1954)

A new chemical analysis of renardite from Katanga has confirmed the formula $Pb(UO_2)_4(PO_4)_2(OH)_4-7H_2O$. X-ray single crystal study established the unit cell as orthorhombic with the dimensions a=16.07 angstroms, b=17.50, c=13.7. Renardite is isostructural with both dewindtite (a=16.07, b=17.50, c=13.62) and phosphuranylite. The chemical composition of dewindtite, however, cannot be reconciled with that of renardite on this basis. Phosphuranylite is probably the calcium analogue of renardite, with the formula $Ca(UO_2)_4(PO_4)_2(OH)_4-7H_2O$. (Auth)

<292>
Frondel, C., and R. Meyrowitz, Harvard University, Cambridge, MA; USGS, Washington, DC

Studies of Uranium Minerals (XIX): Rutherfordine, Diderichite, and Clarkeite. The American Mineralogist 41:127-133. (1956)

Rutherfordine, diderichite, and a synthetic uranyl carbonate obtained by heating UO_3 in water under 15,000 psi CO_2 at 300 degrees C gave identical x-ray powder patterns, and on analysis yielded the same formula $[(UO_2)(CO_3)]$. The name rutherfordine has priority. Two new localities are recorded for rutherfordine at Beryl Mountain, N.H. and Newry, Maine, where it occurs as crusts and aggregates of orthorhombic(?) fibers; biaxial positive, with nX=1.720-1.723, nY=1.728-1.730, nZ=1.755-1.760; Y along the fiber length. Clarkeite is described from its second known locality, the Ajmer district, Rajputana, India, where it occurs as a microcrystalline, chocolate-brown alteration product of uraninite in pegmatite. Analysis yielded the formula $(Na, Ca, Pb, Th, H_2O)_2U_2(O, H_2O)_7$; isostructural with $Na_2U_2O_7$ and CaU_2O_7. Specific gravity is 6.29, mean index of refraction 1.94-1.97. (Auth) (JMT)

<293>
Frondel, J.W., Harvard University, Cambridge, MA

Studies of Uranium Minerals: Zeunerite. The American Mineralogist 36:249-255. (1951)

X-ray study by the Weissenberg method on zeunerite from Tintic, Utah, gave a space group P(sub 4)/nmm-D(sub 4h)7 and cell dimensions a(sub 0)=7.13 angstroms, c(sub 0)=8.83, with a(sub 0):c(sub 0)=1:1.238. The unit cell contents are $Cu(UO_2)_2(AsO_4)_2-8H_2O$. The calculated specific gravity is 3.79; the measured specific gravity of Schneeberg material is 3.64. Study of synthetic zeunerite indicated the existence of two and possibly three hydrates, one with 16 to 10 H_2O, one with 8 to 5 H_2O, and possibly a still lower hydrate. In this respect, the synthetic material is similar to autunite and torbernite, both of which have been found in fully hydrated forms and as lower hydrates, meta I and meta II. Natural zeunerite corresponds in water content and x-ray structure to meta-autunite I and to synthetic zeunerite with 8 H_2O. Variation in water content affects both the optical and fluorescent properties of the material.

<294>
Frondel, J.W., and F. Cuttitta, USGS, Washington, DC

Studies of Uranium Minerals (XII): The Status of Billietite and Becquerelite. The American Mineralogist 38:1019-1024. (1953)

Billietite ($BaO-6UO_3-11H_2O$) was found to be a valid mineral species and isostructural with becquerelite ($7UO_3-11H_2O$). Chemical analyses and Weissenberg x-ray studies on two specimens of billietite gave: (1) BaO 6.88 percent, UO_3 82.76 percent, H_2O 8.97 percent, SiO_2 0.76 percent, CaO 0.30 percent, for a total of 99.67 percent; a(sub 0) 14.25 angstroms, b(sub 0) 12.08, c(sub 0) 15.06 with four formula units per unit cell; alpha 1.730, beta 1.810, gamma 1.815; sp. gr. 5.32 (meas.), 5.33 (calc.); (2) BaO 7.41 percent, UO_3 84.39 percent, H_2O 8.68 percent for a total of 100.48 percent; a(sub 0) 13.98 angstroms, b(sub 0) 12.08 angstroms, c(sub 0) 15.06 angstroms; alpha 1.725, beta 1.780, gamma 1.790; sp. gr. 5.36 (meas.), 5.40 (calc.). Space group Pnma. Billietite is orthorhombic with 2V(-) 35 degrees; X pale yellow, Y and Z golden yellow. A new analysis and x-ray study of becquerelite gave UO_3 89.53 percent, H_2O 8.95 percent, SiO_2 1.82 percent; a(sub 0) 13.92 angstroms, b(sub 0) 12.45 angstroms, c(sub 0) 15.09 angstroms; alpha 1.730, beta 1.805, gamma 1.820; sp. group 5.3 (measured), 5.6 (calculated). From this new analysis the old formula for becquerelite ($2UO_3-3H_2O$) has been revised to $7UO_3-11H_2O$, analogous to the formula for billietite, and there are four formula units per unit cell. Space group Pnma. Becquerelite is orthorhombic, 2V(-) 30 degrees; X yellow, Y and Z deep golden yellow. (Auth) (JMT)

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<295>
Frondel, J.W., and F. Cuttitta, USGS, Washington, DC

Studies of Uranium Minerals (XVI): An Alteration Product of Ianthinite. The American Mineralogist 39:1019-1029. (1954)

A specimen from Katanga labeled as ianthinite in the Harvard University mineral collection was analyzed. The mineral resembled ianthinite in hand specimen, but chemical analysis gave only a trace of UO_2 and a formula of $UO_3 \cdot 2H_2O$, whereas ianthinite reportedly contains only tetravalent uranium. The mineral was thought to be an alteration product of ianthinite in which the tetravalent uranium was almost completely oxidized to hexavalent uranium. X-ray Weissenberg study, using copper radiation, gave sharp lattice patterns with a(sub 0)=7.17 angstroms, b(sub 0)=11.46, and c(sub 0)=15.20; a(sub 0):b(sub 0):c(sub 0) =0.6257:1:1.311. The measure specific gravity of the specimen was slightly less than 3.5 and the calculated specific gravity was 3.567, assuming 9 formula units of $UO_3 \cdot 2H_2O$. (JMT)

<296>
Fuchs, L.H., and E. Gebert, Argonne National Laboratory, Lemont, IL

X-Ray Studies of Synthetic Coffinite, Thorite and Uranothorites. The American Mineralogist 43:243-248. (1958, March)

X-ray data are presented for synthetic coffinite, thorite, and several uranothorites. The cell constants obtained for coffinite are a=6.981 plus or minus 0.004kX, c=6.250 plus or minus 0.005kX; for thorite a=7.128 plus or minus 0.008kX, c=6.314 plus or minus kX. Intermediate constants determined for several uranothorites indicate a continuous solid solution between $USiO_4$ and $ThSiO_4$. Coffinite and thorite are isostructural with zircon. The oxygen positions for coffinite are u=0.180 plus or minus 0.010, v=0.347 plus or minus 0.010 and for thorite u=0.166 plus or minus 0.010, v=0.347 plus or minus 0.010. No changes were observed either in line intensities or in cell constants with OH removed from the hydrothermal preparations. (Auth) (JMT)

<297>
Gabelman, J.W.

Fixation of Uranium. Migration of Uranium and Thorium - Exploration Significance, J.W. Gabelman. The American Association of Petroleum Geologists, Tulsa, Oklahoma, (pp. 75-76), 168 pp. (1977)

Although generally mobile in the hexavalent state, uranium can be stabilized by precipitation as arsenate, phosphate, or vanadate. Uranium reduction and precipitation of primary uranous silicate or uranous oxide require an external agent, most commonly organic material of which coals of bituminous or lower rank are the most efficient. Uranium migrating in continental groundwater has little opportunity for fixation. Even in arid climates, the relatively insoluble hexavalent vanadates are never from carbon "trash" concentrations, and these have been oxidized from primary unoxidized pitchblende deposits at shallow depths. The exact mechanisms of reduction and fixation by organic matter have been extensively investigated, but still are not well understood. Bacterial H_2S has been put forth as the reductant, but some investigators have failed to find bacteria in uranium deposits and the distribution geometry of uranium and organic matter in unoxidized deposits is more commonly noncorrelative than correlative. (JMT)

<298>
Gorman, D.H., University of Toronto, Toronto, Ontario, Canada

Studies of Radioactive Compounds: V-Soddyite. The American Mineralogist 37(5-6):386-393. (1953, May)

Soddyite is a rare hydrous uranium silicate. It occurs as idiomorphic crystals often in groups or clusters, which are sometimes divergent. Soddyite is greenish-yellow for the cross-fibre type, canary yellow for the opaque material and amber yellow for the transparent crystals. The density of a clean cluster of crystals was 4.70 plus or minus 0.01, and two cleavages were noted: (001) perfect and (111) good. Soddyite's chemical formula is $5UO_3 \cdot 2SiO_2 \cdot 6H_2O$. The mineral is orthorhombic with a=8.32, b=11.21, and c=18.71 angstroms. The space group is Fddd. Soddyite is optically negative, pleochroic, X colorless, Y very pale yellow, and Z pale yellow-green. (JMT)

<299>
Gorman, D.H., and E.W. Nuffield, University of Toronto, Toronto, Ontario, Canada

Studies of Radioactive Compounds: VIII-Uranophane and Beta-Uranophane. The American Mineralogist 40(7-8):634-645. (1955, July)

Uranophane [$CaO \cdot 2UO_3 \cdot 2SiO_2 \cdot 6H_2O$] is the most common uranium silicate mineral. It occurs as idiomorphic crystals which are prismatic or acicular, sometimes reticulate, but more often in divergent clusters or tuffs. The color is variable, typically lemon yellow, canary yellow, orange yellow, and very often, pale yellow. Uranophane and beta-uranophane are dimorphous with composition. Uranophane is monocline with a=15.87, b=7.05, and c=6.66 angstroms. Beta is equal to 97 degrees and 15 minutes. Beta-uranophane is monoclinic and a=6.64, b=15.55, and c=14.01 angstroms. Beta is equal to 91 degrees. (JMT)

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<300>
Gotman, Ya. D., V.N. Polyakova, and A.K. Sigata

Another Variety of Brannerite. Doklady Akad Nauk SSSR, Earth Sciences Section 179:124-125. (1967)

A uranium titanate has been found in the USSR that has much in common with minerals of the brannerite group. Unlike ordinary hypothermal brannerite, however, its new variety is a product of hydrothermal activity at moderate and low temperatures. The mineral occurs as continuous masses and, less commonly, accumulations of prismatically elongate crystals up to 0.08 mm in length in the cement of a fault breccia of metamorphic or granitoid rocks, where it is closely associated with pyrite and marcasite. The formation of the titanate-bearing breccia was precised by intense metasomatism, with replacement of host rock by an aggregate of pyrite, anderite, dolomite, and potassium feldspar. The uranium titanate is black but becomes dark brown in powder. It has a strong resinous luster, a conchoidal fracture, a specific gravity of 4.32, and a hardness of 5.1 on the Mohs scale. Optically the mineral is isotropic and when x-rayed in the natural state, the mineral is amorphous. (JST)

<301>
Gritsaenko, G.S., L.N. Belova, R.V. Getseva, and K.T. Savelyeva

Mineralogical Types of Oxidation Zones of Hydrothermal Uranium and Sulphide-Uranium Ores of the USSR. Peaceful Uses of Atomic Energy, Vol. 2, Survey of Raw Material Resources, Proceedings of the 2nd International Conference, Geneva, Switzerland, September 1-13, 1958. United Nations, New York, (pp. 466-474), 843 pp. (1958)

For uranium deposits there can be distinguished two mineralogical types of oxidation zones: 1) Hydroxide-siliceous type, and 2) Siliceous type proper. For uranium-sulphide deposits three types of oxidation zones can be distinguished: 1) Siliceous-micaceous, 2) Micaceous proper, and 3) Micaceous-limonitic and limonitic proper. Among the oxidation zones studied, the micaceous zones are distinguished by the greatest variety of mineral composition. The distribution of secondary uranium minerals in the oxidation zone in a number of instances shows a definite secondary zonation which is different for uranium proper and sulphide-uranium deposits. Oxidation zone types, as determined by secondary uranium mineralization can also serve as the principal outcrop types. Oxidation zones of the hydroxide-siliceous type most easily lend themselves to assessment of deposits by the outcrops. Outcrops of phosphate-arsenate ores (oxidation zone of the micaceous type) characterize heavily depleted sections of the deposit and do not go beyond low-grade noncommercial ores. Considering uranium's high migratory ability and the comparatively low stability of its hypergenic materials, highly significant for assessing its outcrops is the identification of such uranium-bearing minerals which firstly should be extensively distributed and preserved in all oxidation zones, and secondly would permit judgment of the relative concentration of this element in ore bodies. These requirements are satisfied primarily by iron hydroxides. The establishment of the dependence between the uranium content of limonites and the character of the mineralization of zones increases the significance of mineralogical criteria in assessing a deposit, especially in the case when oxidation zones are poor in uranium minerals or do not contain them at all. Along with minerals and mineral associations considered, some significance may also be of some modern new formation (sulphates, carbonates, and molybdates of uranium which in some instances can be used for reassessing old mine workings and dumps for uranium content. (JST)

<302>
Gruner, J.W., University of Minnesota, Minneapolis, MN

Concentration of Uranium by Carbon Compounds. Economic Geology 50:542-543. (1955)

It is suggested that the carbon responsible for precipitation of U minerals is derived from more complex carbon compounds including resins (bitumens?), based on the evidence of numerous unmetamorphosed sediments ranging in age from Permian to Tertiary and of world-wide distribution. Another evidence is the common replacement of fossil plant cell walls by reduced U minerals and the association of asphaltite with fossil plants, whereas petroleum, when found with carbonized plants or asphaltite, contains only traces of U (example: Temple Mountain, Utah). There is no visible gradation between oil and asphaltite. The fact that graphitic carbon has no influence on U precipitation is predictable from its inertness; if the carbon were of organic origin and metamorphosed after contact with U, there could be an association. This may be the case in the Algoma-Blind River District, Ontario, though it is doubtful whether brannerite would have formed with the aid of organic carbon. The low solubility of Th would require more than a hot aqueous solution to produce the variety of U-Th minerals found in pegmatites. Examples of hydrocarbon polymerization by irradiation to form thucholite or asphaltite in metamorphosed rocks are difficult to find. (LKH)

<303>
Hoekstra, H.R., and L.H. Fuchs, Argonne National Laboratory, Lemont, IL

Synthesis of Coffinite - $USiO_4$. Science 123:105. (1956)

A procedure of synthesizing coffinite ($USiO_4$) by a hydrothermal process is discussed. One milli-mole each of uranium tetrachloride and sodium metasilicate are dissolved in 10 ml of water. Sodium hydroxide solution is added dropwise to the uranium silicate solution until a stiff gel forms near the neutral point. Enough additional base is added to make the mixture slightly alkaline (pH 8 to 10). The gelatinous precipitate is then centrifuged and transferred to a vitreous silica tube, which is placed in an Inconel bomb tube. These operations are carried out in a nitrogen atmosphere to prevent oxidation of the uranium. The sealed Inconel tube is heated 4 to 5 days at 250 degrees C to crystallize the $USiO_4$. The synthetic coffinite appears as a bluish-green solid in the reaction products. The material prepared to date appears to be isotropic under the microscope, but x-ray powder patterns confirm the presence of tetragonal crystals of coffinite. Quartz or cristobalite have also been identified as contaminants in all coffinite preparations. (JMT)

MINERALOGY

<304>
Hoeve, J., and T.I.I. Sibbald, Saskatchewan Research Council, Saskatoon, Saskatchewan; Saskatchewan Geological Survey, Regina, Saskatchewan

Mineralogy and Geological Setting of Unconformity-Type Uranium Deposits in Northern Saskatchewan. Uranium Deposits, Their Mineralogy and Origin, Short Course Handbook, Volume 3, M.M. Kimberley, (Ed.). University of Toronto Press, Toronto, Canada, Ch. 19, (pp. 457-474), 521 pp. (1978, October)

The period of 1.25 to 1.0 billion years ago is believed to be time interval at which time the unconformity-type uranium deposits formed throughout the Athabasca basin. This interval post-dates the deposition of the Athabasca Formation and is approximately coincident with an episode of Grenville-age mafic magmatic activity within the basin. The mineralization of these deposits is spatially related to the unconformity which underlies the Athabasca Formation, but is unrelated to pre-Athabasca weathering. Frequently, the mineralization is associated with reverse faults that parallel the bedding planes in pre-Athabasca host rocks of Aphebian (Early Proterzoic) age and it commonly is associated with graphitic Aphebian rocks. Host-rock alteration characterized by intensive chloritization and, at least locally, by tourmalinization accompanied mineralization. This host-rock alteration involved the leaching of silica, calcium, iron, alkali elements and the introduction on a large scale of magnesium and probably also boron. Mineralogical and geochemical characteristics of the deposits are similar to those of vein deposits of complex mineralogy in the Beaverlodge district. Redox reactions, as exemplified by oscillations between oxidizing and reducing conditions in the Rabbit Lake orebody have probably played an important role in the formation of the deposits. (JHT)

<305>
Hoeve, J., and T.I.I. Sibbald, Saskatchewan Research Council, Saskatoon, Saskatchewan; Saskatchewan Geological Survey, Regina, Saskatchewan

Uranium Concentration Related to the Sub-Athabasca Unconformity, Northern Saskatchewan, Canada. Uranium Deposits, Their Mineralogy and Origin, Short Course Handbook, Volume 3, M.M. Kimberley, (Ed.). University of Toronto Press, Toronto, Canada, Ch. 20, (pp. 475-498), 521 pp. (1978, October)

Several uranium deposits have been discovered within the Middle Proterozoic Athabasca Basin of northern Saskatchewan during the past decade. These deposits display a spatial association with the sub-Athabasca unconformity and also with graphitic basement rocks. Although a number of studies of the deposits have been made, their genesis is still widely debated. Two broad schools of thought have emerged: (1) the near-surface-supergene school, and (2) the magmatic hydrothermal or metamorphic-hydrothermal school. The spatial association between the uranium mineralization and the sub-Athabasca unconformity provides the main argument in support of a near surface-supergene origin. Those who support such an origin generally equate the alteration observed in and around the orebodies with pre-Athabasca weathering. Uranium is thought to have been leached by oxidizing ground waters from weathered basement rocks and/or pre-existing Hudsonian vein-type deposits and to have been redeposited in suitable traps by chemical reduction. The magmatic-hydrothermal and metamorphic-hydrothermal theories are attractive because they are compatible with the fluid inclusion and age dating studies, and also the distinctly epigenetic relationship of mineralization to the Athabasca Formation. The main short coming in this theory is the lack of an adequate explanation for the undeniable spatial association with the sub-Athabasca unconformity. The authors put forth another theory: the diagenetic-hydrothermal hypothesis. This theory related mineralization to diagenetic processes within the Athabasca Formation and attributes the spatial association of deposits with the sub-Athabasca unconformity to interaction of heated diagenetic solutions with metamorphic rocks of the basin floor. (JHT)

<306>
Hurlbut, C.S., Jr., Harvard University, Cambridge, MA

Studies of Uranium Minerals (XV): Schroeckingerite from Argentina and Utah. The American Mineralogist 39(11-12):901-907. (1954, November)

Schroeckingerite $[NaCa_3UO_2(CO_3)_3SO_4F.10H_2O]$ samples from the Shinarump No. 3 Mine, near Moab, Utah and from San Isidro, Argentina were studied. Samples from both areas had physical properties similar to those of the mineral as described from other localities, with the exception that both had somewhat higher specific gravities. Unit space cell dimensions, space group, physical and optical properties of the schroeckingerite are discussed. (JHT)

<307>
Kimberley, M.M., University of Toronto, Earth and Planetary Sciences, Erindale College, Mississauga, Ontario, Canada

Origin of Stratiform Uranium Deposits in Sandstone, Conglomerate, and Pyroclastic Rock. Uranium Deposits, Their Mineralogy and Origin, Short Course Handbook, Volume 3, M.M. Kimberley, (Ed.). University of Toronto Press, Toronto, Canada, Ch. 18, (pp. 339-381), 521 pp. (1978, October)

The origin of stratiform uranium deposits in sandstone, conglomerate, and pyroclastic rock, through the world is discussed. Phanerozoic stratiform deposits in Quaternary deposits in Italy, in Permian mineralization in the Austro-Italian Alps, in Niger, Africa, and in the Colorado Plateau are compared with the Middle Precambrian Witwatersrand and Elliot Lake stratiform uranium deposits. This comparison indicates that chemical processes may have been essential in all cases. Dissolution of volcanic gas in Middle Precambrian groundwater may have produced the observed concentrations of pyrite in clastic sedimentary rocks. Weathering of pyrite may, in turn, have mobilized uranium, thorium, and either gold or rare-earth elements into shallowly-buried fluviatile sediments. Subsequent intrabasinal erosion could have resulted in some placer sedimentation of ore mineral aggregates, even if the earths atmosphere had been oxygenic.

<308>
Langford, F.F., University of Saskatchewan, Department of Geological Sciences, Saskatoon, Saskatchewan, Canada

Origin of Unconformity-Type Pitchblende Deposits in the Athabasca Basin of Saskatchewan. Uranium Deposits, Their Mineralogy and Origin, Short Course Handbook, Volume 3, M.M. Kimberley, (Ed.). University of Toronto Press, Toronto, Canada, Ch. 21, (pp. 485-499), 521 pp. (1978, October)

> A number of theories have been put forth in attempt to explain the origin of the Athabasca Basin unconformity-type uranium deposits. These hypotheses can be divided into two major schools of thought based upon whether the uraniferous solutions ascended or descended. Ascending uraniferous solutions have two possible sources: (1) from magmatic or anatectic sources and (2) from metamorphic sources. The advocates of descending uraniferous solutions differ as to the time the mineralizing ground water solutions. One group of theories proposes mineralization came after the deposition of a thick sequence of cover rocks, while another group of theories put the mineralizing ground water during the early deposition of the first 30 meters of cover rocks. The favored hypothesis is that pitchblende vein deposits were formed by the fluvial processes which formed the initial sandstone above the unconformity and that the deposits subsequently were subjected to diagenetic recrystallization during deep burial. This hypothesis explains many of the features of these deposits, and it explains why these deposits only occur at unconformities overlain by sandstone of fluvial origin. (JHT)

<309>
Lindsey, D.A., USGS, Denver, CO

Mineralization Halos and and Diagenesis in Water-Laid Tuff of the Thomas Range, Utah. USGS Professional Paper 818-B; 59 pp. (1975)

> Pliocene water-laid tuffs are widespread in western Utah and provide the host rock for beryllium-fluorite mineralization at Spor Mountain. A systematic study of the mineral and chemical composition of the tuff in the southern part of the Thomas Range was undertaken to examine regional effects of mineralization at Spor Mountain and to differentiate these from the effects of other petrologic processes. Important factors in tuff petrogenesis are beryllium-fluorite mineralization, three stages of diagenetic alteration of glass, concentration of calcite versus silica, and concentration of detrital heavy minerals. Diagenesis has been of major importance in changing the chemical composition of the tuff. Soda, K_2O, F, Rb, U, Mn, and Pb are depleted during zeolitization and MgO, Ba, Cr, and Sr are concentrated. Potassium feldspar diagenesis did not affect the chemical composition of the tuff. Possible release of F, U, and Mn during zeolitization suggests a potential diagenetic contribution of these elements to ore deposits, notably the sedimentary uranium deposits found nearby. (JHT)

<310>
Makarov, E.S., and L.I. Anikina, V.I. Vernadskii Institute of Geochemistry and Analytical Chemistry, Moscow, USSR

Crystal Structure of Umohoite $[UMoO_6(H_2O)_2 \times 2H_2O]$. Geochemistry 1:14-21. (1963)

> The parameters of the monoclinic unit cell of umohoite are a=6.32 angstoms, b=7.50 angstroms, c=57.8 angstroms, and beta=94 degrees. The space group is P2(sub 1/c) and Z=16. The crystal structure has been determined with R approximately 20. The coordinates of the atoms are given in a table. Umohoite has a well defined layer structure with pseudohexagonal layers of ordered uranium, molybdenum, and oxygen atoms arranged normal to the z axis and parallel to the cleavage. The spaces between the layers are occupied by 0 to 2 molecules of zeolitic water. The crystalochemical formula of umohoite is $[UMoO_6(H_2O)_2 \times (0-2)H_2O]$. (Auth)

<311>
Makarov, E.S., I.M. Lipova, I.F. Dolmanova, and A.A. Melik'yan, V.I. Vernadskii Institute of Geochemistry and Analytical Chemistry, Moscow, USSR

Crystal Constitution of Uraninites and Pitchblendes. Geochemistry 3:229-252. (1960)

> Petrographic studies of minerals of the uraninite-pitchblende series were carried out to determine the chemical composition, density, and lattice constants of these minerals. In addition, the numbers of atoms and formula units in the unit cell were calculated, the crystal structure was determined, and the manner of alteration of the structure by oxidation was studied. Uraninites and pitchblendes were found to have a primitive cubic lattice related to the space group Th6-Pa3 rather than a face-centered lattice of the fluorite type, as has been previously assumed. For all the specimens studied, the number of atoms in the unit cell was lower than 12. This value was in line with a fluorite type of structure. Atomic coordinates for $UO_{2.33}$ pitchblende having 3.15 formula units in the unit cell are listed. According to the new structure, the hexavalent uranium atoms in uraninites and pitchblendes for UO_2^{+2} uranyl groups, and the uranium-oxygen distance is 1.90 angstroms. Excess oxygen atoms occupy the 4 (a) and 4 (b) interstices of the lattice to compensate the charge of the uranyl groups. The number of these atoms is equal to the number of hexavalent uranium atoms. With increased oxidation of the uraninites and pitchblendes, the numbers of uranyl groups and excess oxygen atoms in the structure increase while the number of atoms and corresponding formula units in the cell are decreased. As a result, the cell dimensions and the density decrease. On the basis of this study and literature data, the chemical composition of uraninites and pitchblendes is best expressed by the formula (U+4, U+6, Pb, Th, RE, Ca)O (sub 1.90-2.50). (Auth) (JHT)

<312>
Moench, R.H., USGS, Denver, CO

Properties and Paragenesis of Coffinite from the Woodrow Mine, New Mexico. The American Mineralogist 47:26-33. (1962, January)

The Woodrow mine is in the central part of the Laguna uranium mining district, about 45 miles west of Albuquerque, New Mexico and 10 miles north of Laguna Indian Pueblo. The deposit occupies a nearly vertical sandstone pipe, or cylindrical collapse structure in the Morrison Formation of Jurassic age. Unoxidized ore is composed of coffinite and uraninite, which typically are extremely finely divided and intimately mixed with a carbonaceous substance. Pyrite and marcasite are also abundant, and small amounts of chalcopyrite, galena, wurtzite, cobaltite, barite, and carbonate minerals are present. The uranium deposit is small but of high grade, averaging more than 1 percent U_3O_8 and the vanadium content is very low, with a uranium-vanadium ratio of about 50:1. Well crystallized coffinite found as a vug filling in the mine is botyoidal with radially fibrous internal structure. In polished surfaces the mineral is hard, gray, isotropic, and has a reflectivity of 7.5 percent in orange light. In transmitted light it is anisotropic, showing parallel extinction, with the optic and crystallographic "c" axes parallel to the fibers. It is brown and slight pleochroic, from pale yellow brown parallel to the fibers to be brown normal to the fibers. The refractive indices are near 1.74 and the birefrigence is less than 0.01 and variable. Textural relations, combined with data from other specimens of Woodrow ore, suggest that sulfide and uranium mineralization were related in time as well as space. (JBT)

<313>
Morton, R.D., University of Alberta, Department of Geology, Edmonton, Alberta

The Identification of Uraniferous Minerals. Uranium Deposits, Their Mineralogy and Origin, Short Course Handbook, Volume 3, M.M. Kimberley (Ed.). University of Toronto Press, Toronto, Canada, Ch. 5, (pp. 141-183), 521 pp. (1978, October)

Sequential identification procedures of uranium minerals are discussed briefly in this chapter. Following the discussion, four extensive tables are provided for use in uranium mineral identification. (JBT)

<314>
Olson, J.C., and W.C. Overstreet, USGS, Washington, DC

Geologic Distribution and Resources of Thorium. USGS Bulletin 1204; 61 pp. (1964)

Concentrations of thorium are mainly found in four geologic environments: (1) placer deposits consisting of beach, fluviatile, and residual concentrations of heavy thorium-bearing minerals; (2) epigenetic deposits, which include vein or lode deposits and contact-metamorphic or replacement bodies; (3) sedimentary rocks, which comprise ancient placers, thorium-bearing dolomite, and deposits in conglomerates; and (4) igneous and metamorphic rocks which include thorium-rich granite, alkalic rocks, carbonatite, fenite, pegmatite and pegmatitic migmatite, and thorium-rich zones in metamorphic rock. Known thorium reserves of the United States are estimated at about 100,000 tons of ThO_2, but total resources are probably much larger owing to the lack of exploration that has been done for it in comparison with other metals. Known world reserves of high-grade deposits and easily mined placer deposits are about 740,000 tons of ThO_2. (JBT)

<315>
Reynolds, R.L., and M.B. Goldhaber, USGS, Denver, CO

Iron-Titanium Oxide Minerals and Associated Alteration Phases in Some Uranium-Bearing Sandstones. Journal of Research of the USGS 6(6):707-714. (1978, November)

Detrital Fe-Ti oxide minerals of the ulvospinel-magnetite and ilmenite-hematite solid solution series are common in uranium-bearing sandstones and it is believed these minerals may record important information on the geochemical environment of deposition of uranium in sandstone. Samples from five mineralized formations in three of the major uranium-producing districts of the western United States were examined for Fe-Ti oxide minerals and their alteration products. Alteration of Fe-Ti oxide minerals in oxidizing environments formed secondary products that are distinct from those produced under reducing conditions. Oxidation of sulfidized Fe-Ti oxide minerals, by the processes that formed uranium rolls, produced ferric oxide minerals (limonite) having textures that mimic those of the iron disulfides. Titanomagnetite and titanohematite have been severely depleted in the ore-bearing zones of some uranium deposits. The alteration of detrital Fe-Ti oxide minerals near uranium ore deposits may produce characteristic signatures in the magnetization of the sandstone. Knowledge of the distribution and magnetic properties of these minerals can aid in interpreting data from total magnetic-field and magnetic-susceptibility surveys of uranium deposits. (JBT)

<316>
Reynolds, R.L., M.B. Goldhaber, and R.I. Grauch,
USGS, Denver, CO

Uranium Associated with Iron-Titanium Oxide
Minerals and Their Alteration Products in a South
Texas Roll-Type Deposit. USGS Circular 753;
Short Papers of the US Geological Survey
Uranium-Thorium Symposium, 1977, J.A. Campbell
(Ed.). (pp. 37-39). 75 pp. (1977)

Electron microprobe and petrographic studies have been conducted on a suite of ore-bearing samples from a roll-type uranium deposit in south Texas. Each sample from the nose and lower limb of the roll was separated into size fractions less than and greater than 44 m, and each size fraction was further subdivided by bromoform density separation into heavy and light mineral groups. Uranium in the light, fine-grained fraction appeared to be predominately associated with silicon, calcium, potassium, and aluminum. Uranium in the heavy fractions occurred primarily with titanium and iron, and to a lesser extent with sulfur, calcium, and silicon. Uranium was frequently observed in association with a TiO_2 phase that originates largely, if not exclusively, from the alteration of iron-titanium oxide minerals. It is possible that some uranium occurs as a silicate (coffinite?). The TiO_2 phase in the ore-bearing zones originated primarily by expulsion of Ti during the replacement of detrital Fe-Ti oxides (titanomagnetite and titanohematite) by iron sulfide minerals. Uranium occurs in association with TiO_2 on the margins of relict Fe-Ti oxide grains in various stages of conversion to FeS_2. Where replacement is complete, uranium-bearing TiO_2 surrounds the sulfides. Uranium occurs not only in authigenic TiO_2 surrounding altered Fe-Ti oxides, but also in TiO_2 within the altered grains. Alteration of Fe-Ti oxide minerals has not led in every case to the segregation into discrete phase. In some titanomagnetite and titanohematite grains in mineralized rock, the authors observed other alteration phases petrographically distinct from TiO_2, that contain abundant titanium, iron, and sulfur together with lesser amounts of uranium, silicon, and calcium. (JMT)

<317>
Riese, W.C., D.G. Brookins, and R.S. Della Valle,
Gulf Mineral Resources Company, Albuquerque, NM;
University of New Mexico, Albuquerque, NM

SEM Investigation of Paragenesis of Uranium
Deposits, Grants Mineral Belt, New Mexico. AAPG
Bulletin 63(4):693. (1979, April)

Scanning electron microscopy (SEM) study of authigenic minerals in the Westwater Canyon Member of the Morrison Formation (Late Jurassic) indicates that mineral compositions vary within and adjacent to sandstone-type uranium deposits. Montmorillonite is the dominant clay mineral in the reduced ground downdip of the orebody; chlorite is enriched in the ore zones; and kaolinite and altered montmorillonite dominate in the "oxidized" ground updip of the ore. Our data also suggest that clay minerals, not pyrite or hematite, may locally be the iron-bearing species of importance. Although it is not possible to make positive identification of organic materials in SEM photomicrographs, materials deduced to be organic in nature postdate the beginning of authigenic clay formation. This implies that these materials may be carriers of uranium in the groundwater system from which the ore deposits precipitated. Identification of these patterns of clay-mineral alteration and the role that organic materials may play as transporting media may significantly alter our exploration techniques. These patterns may be especially useful tools in areas where the orebodies are known to be removed from the iron species redox interface. (Auth)

<318>
Rimsaite, J., Canada Geological Survey, Ottawa,
Ontario, Canada

Mineral Assemblages at the Rabbit Lake Uranium
Deposit, Saskatchewan: A Preliminary Report.
Geological Survey of Canada Paper 77-1B, Report
of Activities, Part B, (pp. 235-246), 350 pp.
(1977)

Uranium mineralization at the Rabbit Lake deposit, northeastern Saskatchewan, occurs in the hanging wall of a northeasterly-trending thrust fault in Aphebian metasediments of the Wollaston Lake Fold Belt, just below the unconformity with the overlying Athabasca Formation. The metasediments - quartzite, meta-arkose, biotite paragneiss, calc-silicate rocks, and marble - are brecciated and transected by pegmatites. A mineralogical-geochemical investigation of specimens collected in 1975 yielded the following information: Radioactive elements occur in nine mineral groups and various modes; together with Co, Ni, Cu, Se, Th, and REE minerals, they demonstrate the mineralogical complexity of the deposit. Contacts between "primary" pitchblende and host rock are unclear and are commonly marked by recrystallization and alteration. In the high-grade ore, pitchblende is the main U-mineral; its fracturing and partial resorption and alteration along those fractures may indicate that all secondary U-minerals were derived from it. Below the thrust fault, radioactive minerals include "yttrialite" grains containing U, Th, and REE, and type 5 pitchblende, which rims Ti-minerals. Marked differences observed in Pb/U ratios in the U-minerals are attributed to (a) temporal differences in crystallization of primary and secondary U-minerals and in the natural accumulation of radiogenic lead, (b) migration and depletion of Pb during remobilization of pitchblende, and (c) recrystallization of liberated U and Pb in different proportions to form secondary U-Pb minerals. The pyroxene-amphibole-biotite layers in the gneisses and their alteration products are similar in composition above and below the main thrust fault. (LKM)

MINERALOGY

<319>
Ross, V., Harvard University, Cambridge, MA

Studies of Uranium Minerals (XXII): Synthetic Calcium and Lead Uranyl Phosphate Minerals. The American Mineralogist 41:915-926. (1956)

The uranium minerals phosphuranylite, renardite, "dewindtite," dumontite, parsonsite, and the phase lead-autunite were investigated synthetically to establish idenity and the conditions of deposition. In the acid range, autunite and parsonsite predominate. Under neutral and alkaline conditions, there exist a number of renardite-type phases of variable lead content with closely related x-ray spectra and properties. It is suggested that "dewindtite" be discredited as a distinct mineral species. A phase has been prepared that corresponds chemically, but is not identical to dumontite on the basis of limited, existing data on the mineral. The methods of synthesis and resultant phases in the systems calcium- and lead-uranyl-phosphate-water are described. Chemical, optical and x-ray data are included. (Auth)

<320>
Sharp, B.J., AEC, Washington, DC

Uranium in Fluorite, Spor Mountains, Utah. Guidebook to the Geology of Utah, No. 17, (pp. 14). (1963)

The fluorite pipes of Spor Mountain contain variable quantities of uranium associated with the fluorite. These pipes are described in detail by M.H. Staatz and F.W. Osterwald in USGS Bulletin 1069. The U.S. Atomic Energy Commission sampled many of the pipes for uranium and the results indicated that some of the fluorite contained nearly commercial quantities of uranium. Yellow secondary minerals occur locally in the fluorite, but for the most part, the uranium ion apparently substitutes for the calcium ion in the crystal lattice of the fluorite. Although this intimate association renders the uranium non-amenable in existing uranium mills, it may be possible to extract some as a byproduct in a hydrofluoric acid mill. The fluorite pipes at the southern end of Spor Mountain contain about 8 times as much uranium as those at the north end and those in between show a general gradational increase in a southern direction. The Bell Hill pipe is the most significant fluorite pipe as far as uranium is concerned. Near commercial grade uranium samples have been taken from the lowest levels of the pipe, as well as near the surface and from many places in between. The Bell Hill pipe is considered to be near the center of a high uranium zone in fluorite, and any pipes which may be discovered in this area would probably be high in uranium content. (Auth)

Cited as a reference in NURE Contractor Reports.

<321>
Stieff, L.R., T.W. Stern, and A.M. Sherwood, USGS, Washington, DC

Coffinite, a Uranous Silicate with Hydroxyl Substitution: A New Mineral. The American Mineralogist 41(9-10):675-688. (1956, September)

Coffinite [U(SiO4)1-x(OH)4x] is a uranous silicate that shows substitution of (OH)4-4 for (SiO4)4-. The mineral was named for Reuben Clare Coffin. Along with uraninite, coffinite is a major uranium mineral in the unoxidized ore of the Colorado Plateau. In hand specimens, coffinite is black with many samples having an adamantine luster, resembling that of a high rank coal. X-ray diffraction powder studies indicate that coffinite is tetragonal and isostructural with zircon. The specific gravity of coffinite-bearing material is variable, with a maximum of 5.1. Chemical analyses of selected and concentrated impure coffinite material indicated 46.37 to 68.29 percent uranium (UO2) and 5.20 to 8.50 percent silica. Heating, leaching, and alpha-plate studies demonstrated that vanadium, aluminum, and arsenic are present in many samples, probably in place of silicon. (JMT)

<322>
Stokes, W.L., University of Utah, Department of Geological and Geophysical Sciences, Salt Lake City, UT

Relation of Fault Trends and Mineralization, Eastern Great Basin, Utah. Economic Geology 63(7):751-759. (1968)

The association of mineralization with the northeasterly to easterly trending faults in the eastern Great Basin of Utah is considered graphically and statistically. The proximity test was based upon 376 faults in the near vicinity of 94 known mines, and supports the conclusion that the mineralization is strongly associated with the faults. Most of the ore bodies in the Great Basin are genetically related to the relatively obscure fractures that cut diagonally across them rather than to the outlined mountain blocks. (JMT)

Cited as a reference in NURE Contractor Reports.

<323>
Thompson, M.E., B. Ingram, and E.B. Gross, USGS, Grand Junction, CO; USGS, Washington, DC; AEC, Grand Junction, CO

Abernathyite, A New Uranium Mineral of the Metatorbernite Group. The American Mineralogist 41:82-90. (1956)

Abernathyite has the formula K(UO2)(AsO4) x 4H2O. It occurs as transparent, yellow, fluorescent, thick tabular crystals belonging to the tetragonal system, ditetragonal-dipyramidal class (4/m 2/m 2/m). The space group is P4/nmm; a(sub 0)=7.17 plus or minus 0.01 angstroms; c (sub 0)=9.08 plus or minus 0.01 angstroms; a:c=1:1.266; Z=2. Optically, the mineral is uniaxial negative. The hardness is between 2 or 3 and the specific gravity is 3.74. Abernathyite is composed of 9.5 percent K2O; 57.7 percent UO3; 21.6 percent As2O5; 1.5 percent P2O5; 4.6 percent H2O; 9.9 percent H2O+; for a total of 104.8 percent. The mineral was first discovered in 1953 in the Fuemrol mine, Emery County, Utah, by the mine operator, Jess Abernathy, for whom Abernathyite is named. (JMT)

<324>
Tilsley, J.E., David S. Robertson and Associated Limited, 65 Queen Street West, Toronto, Ontario, Canada

Uranium Mineralization in Shallow Intrusive Environments. Uranium Deposits, Their Mineralogy and Origin, Short Course Handbook, Volume 3, M.M. Kimberley (Ed.). University of Toronto Press, Toronto, Canada, Ch. 10, (pp. 281-289), 521 pp. (1978, October)

Uranium deposits formed by degassing of shallowly emplaced, highly-differentiated intrusives are not likely to contain large tonnages of uranium metal. However, uranium reserves in the several-thousand-ton range are possible. A genetic model that has been derived from observations made in areas of economically significant uranium mineralization is discussed in this chapter. The model is applicable in many volcanic and alkaline intrusive environments. (JBT)

<325>
Traill, R.J., Queen's University, Kingston, Ontario, Canada

Synthesis and X-ray Study of Uranium Sulphate Minerals. The American Mineralogist 37(5-6):394-406. (1952, May)

Attempts were made to synthesize the uranium sulfate mineral zippetite. Physical, chemical, optical, and x-ray data for zippeite and four other synthetic products are presented. Artificial zippeite is monoclinic, with a space group of C2/m. Unit cell dimensions are: a=8.81, b=14.13, c=8.85 angstroms. Beta is 104 degrees 15 minutes. Cell contents are 2[(UO2)3(SO4)2(OH)2.8H2O]. Calculated specific gravity is 3.68 and measured specific gravity is 3.66. The artificial zippite is biaxial negative, nX=1.655, nY=1.717, nZ=1.765, X=colorless, Y=pale yellow, and Z=yellow. (JBT)

<326>
White, E.W., The Pennsylvania State University, Department of Mineralogy, University Park, PA

An Investigation of the Mineralogy, Petrography, and Paleobotany of Uranium-Bearing Lignites: Uranium Mineralization in Some North and South Dakota Lignites. NYO-7948; M.S. Thesis; 79 pp. (1958, April 2)

The megascopically visible uranium minerals from eleven deposits of Tertiary lignite from North and South Dakota are characterized on the basis of optical, chemical, X-ray diffraction and dehydration properties. The uranium mineral occurrences are divided into three areas on the basis of stratigraphy and geography. Eleven of the twelve minerals are hydrated uranium phosphates, one is an arsenate. Eleven, including the arsenate, belong to the group of torbernite-metatorbernite minerals. Sodium-autunite Na2(UO2)2(PO4)2.nH2O is found in four of the deposits, and is the first reported occurrence of the mineral in the United States. The other identified minerals include: meta-uranocircite, meta-autunite, hydrogen-autunite, saleeite, sabugalite, abernathyite and hydrogen-autunite. Blockiness of the lignite favors uranium deposition. The minerals have no observed affinity to particular lignite minerals. The sodium-autunite is associated with lignites having a high solubility in water and dilute hydroxide solutions. The uranium minerals in the Cave Hills and Billings County areas appear to have formed after removal by erosion of the overlying beds of volcanic material which are thought to have been the source of the uranium. This indicates that in these areas the uranium must have been precipitated originally in the lignite and subsequently leached and redeposited in the near surface portions of the same or nearby seams. (Auth)(MSW)

<327>
Williams, N.C., Beryllium Resources, Inc., Salt Lake City, UT

Beryllium Deposits, Spor Mountain, Utah. Guidebook to the Geology of Utah, No. 17, (pp. 36-59). (1963)

Beryllium occurs at a number of locations in western Utah and central Nevada. Occurrences in the Sheeprock Mountains, Spor-Topaz Mountain, Deep Creek Range, Snake Range, and elsewhere in the region include many of the most significant, non-pegmatite occurrences known. The habitat of the beryllium occurrence alone sets the Spor Mountain deposits in a class by themselves. The numerous faults in the area served as passageways for the mineralizing solutions, which ascended through the Paleozoic sediments into the overlying volcanic sequence. In the tuff, the solutions were distributed partially along faults and fractures, but dominantly along planar zones of greatest permeability more or less parallel to the original but weak stratification of the tuff. Most of the mineral content of the solutions was precipitated within the tuff, but locally the solutions "leaked" into the overlying rhyolites. Fluorite and minor quantities of beryllium are found in fractures and veinlets in the rhyolite. The beryllium is present chiefly as bertrandite and one of its polymorphs, gel-bertrandite. Fluorite is a common mineral both in the beryllium and non-beryllium bearing zones. Manganese is present in complex mixtures and compounds of various oxides. It is believed that the beryllium was transported as a sodium beryllium fluoride. (JBT)

Cited as a reference in NURE Contractor Reports.

<328>
Armstrong, F.C., USGS, Spokane, WA

Geologic Factors Controlling Uranium Resources in the Gas Hills District, Wyoming. Wyoming Sandstone, R.L. Enyert (Ed.), Proceedings of the 22th Field Conference, 1970. Wyoming Geological Association, Casper, WY, (pp. 31-44), 292 pp. (1970)

The Gas Hills uranium district is in Fremont and Natrona Counties, Wyoming. Uranium was discovered here in 1953, and it has been a major mining and milling location since. The upper member of the Wind River formation, the Puddle Springs Arkose Member, is the host rock for the uranium deposits. It consists of poorly consolidated arkosic sandstone and conglomerate facies with thin discontinuous interbeds of mudstone. The rest of the formation consists of silty sandstone and mudstone which are unfavorable host rocks for uranium. Permeability seems to determine to a great extent whether a particular rock is favorable for uranium deposition or not; openwork conglomerate appears to be a good host rock, whereas fine-grained, only slightly permeable rocks are unfavorable hosts. The ore bodies in the Gas Hills area are considered to be ore rolls, i.e., crescent-shaped in vertical cross section, sinuous in plan. The average thickness is 10-15 feet. Most of the ore rolls are stacked en echelon to form frontal systems. The majority of the unoxidized ore is distributed in the lower part of the upper member of the Wind River formation, but it occurs in other stratigraphic positions as well. Unoxidized ore is dark and normally, the darker the ore the higher the grade. The ore minerals are very fine-grained uraninite and a little coffinite. (Oxidized ore occurred near the surface and was mined out when mining first started). Most production, however, has come from unoxidized ore and all of the reserve is contained in unoxidized ore. The uranium is not distributed uniformly throughout a roll but is normally concentrated in the body of the crescent nearest the concave side. In the Gas Hills, the mineralizing solutions moved from south to north. Production estimates of the recoverable uranium vary from 150 million to 200 million pounds U_3O_8, dependent on the price paid for the ore. (MBW)

<329>
Austin, S.R., Bendix Field Engineering Corporation, Grand Junction, CO

Dissolution and Authigenesis in Host Sandstones. AAPG Bulletin 63(4):686. (1979, April)

Empty or partly empty shells that conform to detrital rather than original crystal shapes of sanidine grains are present in host sandstones of the Morrison Formation. This somewhat paradoxical situation is explained by removal of sodium from a surface layer of the detrital grain during weathering, with concomitant conversion of this layer to microcline, which resists dissolution under conditions prevailing after sedimentation. During compaction, dissolution of this outer layer occurs at pressure points; once this layer is penetrated, dissolution of the interior proceeds along crystallographic directions and removes all or part of the unaltered sanidine. Untwinned microcline also is present as minute crystals within shells and as outgrowths on both detrital potash feldspar grains and (rarely) on the shells. Uraniferous organic material occurs both under and over some outgrowths on detrital microcline, suggesting contemporaneity of outgrowths and organic material. Elsewhere, chlorite, reportedly contemporaneous with coffinite, coats both exteriors and interiors of feldspar shells and thus succeeds feldspar dissolution; calcite supersedes rather than replaces feldspars. Quartz outgrowths are commonly earlier than uraniferous organic material but later than jordisite. Locally, chlorite and/or hematite form total or partial pseudomorphs after pyrite. Rarely, marcasite is partially pseudomorphous after, and forms outgrowths on, pyrite. These and similar observations by others reveal fragments of a paragenetic sequence complicated by the presence of both primary and redistributed ore. Further investigations may complete a sequence useful in determining conditions of mineralization, and thus in the discovery of similar ore deposits. (Auth)

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GENESIS OF DEPOSITS

<330>
Beck, L.S., Saskatchewan Department of Mineral Resources, Precambrian Geology Division, Regina, Saskatchewan, Canada

Genesis of Uranium in the Athabasca Region and Its Significance in Exploration. CIM Bulletin 63(695):367-377. (1970, March)

The Athabasca region forms part of the large Churchill structural province of the Canadian Shield and is underlain by an Archean or Aphebian assemblage of regionally metamorphosed and granitized rocks. The basement complex is characterized by a dominant northeast-trending "grain" imparted by the Hudsonian orogeny and basic dikes cut all the rocks of the region. The region is an important mineralogenic province of vein-type pitchblende, and it contains numerous showings of syngenetic uraninite in pegmatite and crystalline basement rocks. The pitchblende deposits can be divided into two groups on the basis of mineralogy; a large group, comprising over 90 percent of the known occurrences, and a much smaller group with a more complex mineral assemblage. The deposits of simple mineralogy consist of pitchblende accompanied by pyrite, chalcopyrite and galena. The deposits of complex mineralogy consist of pitchblende accompanied by one or more of the following: Co-Ni arsenides and sulfides; Co-Ni-Pb selenides; and native elements (Pt, Ag, Au, and Cu). These deposits are restricted to a narrow belt within the Beaverlodge area, but there is no apparent geological explanation for their restricted geographical location. Most of the uranium deposits occur in subsidiary structures to major faults and the three dominant fault sets, trending east, northeast, and northwest, appear to equally favorable. The deposits occur in a wide variety of rock types, with the largest deposits (with the exception of the Gunnar deposit, which is in a metasomatized paragneiss) occurring in mafic rocks. Red hematitic alteration of wall rocks is a typical feature of the pitchblende zones and a characteristic, thought not infallible, guide to ore. The paragenesis of the pitchblende deposits is complex, but a sequence indicated by several deposits is as follows: (1) introduction of pitchblende in finely divided form accompanied by finely disseminated hematite; (2) brecciation of the host rock and emplacement of colloform pitchblende accompanied solely by calcite at first and later by calcite with other gangue minerals; and (3) further brecciation and emplacement of massive pitchblende, calcite, and sulfides. There is no evidence of any major break in mineralization and it is probable that the stages are transitional and, perhaps, overlapping. The pitchblende deposition occurred at temperatures ranging from 100 to 500 degrees C, and probably at depths of less than 10,000 feet. A loss in pressure and the catalytic reaction with iron are believed to be the critical factors in causing the precipitation of the pitchblende. The structural environment determined which of the two factors was dominant. (JMT)

<331>
Becraft, G.E., USGS, Washington, DC

Uranium in Carbonaceous Rocks in Townsend and Helena Valleys, Montana. USGS Bulletin 1046-G, (pp. 149-164). (1958)

The Townsend Valley is a wide basin about 60 miles long and some 600 square miles in areal extent. All known radioactive anomalies in the valley are in rocks of Oligocene age. The Helena Valley is another wide basin, separated from the Townsend Valley by a broad, low divide northwest of Winston. Quaternary deposits are extensive in the Helena Valley, and as a result, Tertiary rocks are exposed in only a few small areas. A few weak radioactivity anomalies have been noted in rocks similar to the Oligocene rocks northeast of Winston. All of the anomalies in both valleys are in or adjacent to carbonaceous shales in the lower part of of a Tertiary unit which consists of several thick beds of conglomerate, interbedded bentonite, and partly bentonized dark-gray tuffs. Of the 20 localities studied, secondary uranium minerals were noted at five. No primary uranium minerals were noted at any of the localities. The author believes the source of the uranium in the Townsend and Helena Valley deposits is the light-gray and white fine-grained tuffs and lapilli tuffs, samples of which contain 0.002 to 0.009 percent uranium. The uranium was probably leached from the tuffs by meteoric water during bentonization and was concentrated in the carbonaceous shale and lignite. Faulting is common in the Tertiary rocks, but no direct relation of uranium deposits to the faults was found. No other structural controls were apparent in the deposits. (JMT)

<332>
Bell, R.T., Canada Geological Survey, Ottawa, Ontario, Canada

Uranium in Black Shales - A Review. Uranium Deposits, Their Mineralogy and Origin, Short Course Handbook, Volume 3, M.M. Kimberley, (Ed.). University of Toronto Press, Toronto, Canada, Ch. 12, (pp. 307-329), 521 pp. (1978, October)

Uraniferous black shales are nearly always characterized by very thin, persistent laminations, with other primary sedimentary structures conspicuously absent. These shales are typically composed of dark gray, grey brown to black, very fine sand- to clay-sized material with organic carbon present as solid carbon compounds, spores and larger fragments of terrestrial and marine plant origin. Pyrite or marcasite is always present, often in amounts up to several percent. The uranium is associated with the organic fraction, or, in the case of phosphoritic units, with the phosphates. Black shales are recorded from all sedimentary environments except desert-aeolian. Uranium content of the principal ancient black shales is large. In Sweden, the Billingen district covers 500 square kilometers with thickness of uraniferous black shale of about 3 meters and a mean uranium content of 300 ppm. The total amount of uranium in this area is estimated at one million tons. Narke, a second district is estimated to have at least one hundred thousand tons of uranium. The Chattanooga shale, while of considerably lower grade, also holds large amounts of uranium due to its wide distribution. (JMT)

<333>
Brookins, D.G., University of New Mexico,
Albuquerque, NM

Periods of Mineralization in Grants Mineral Belt, New Mexico. AAPG Bulletin 63(4):687. (1979, April)

Geologic observations coupled with laboratory studies indicate several periods of mineralization in the Grants mineral belt. The earliest mineralization is from trend ore in the Ambrosia Lake and Smith Lake districts: Rb-Sr radiometric ages on chlorite formed penecontemporaneously with primary uranium minerals range from 135 to 138 plus or minus 8 m.y. This period of mineralization is within the limits of error for the age of sedimentation obtained on barren ground montmorillonite of 140 to 145 plus and minus 10 m.y., but cross-cutting ore indicates early epigenetic as opposed to syngenetic mineralization. Early formed ore in the Laguna district was remobilized and reprecipitated during some mid-Cretaceous event at 110 to 115 m.y. determined on the basis of Rb-Sr dating. Ore was not derived from the overlying Dakota Formation (Cretaceous), as the Rb-Sr dates for the Dakota and Mancos formations are 92 plus and minus 6 m.y. and 85 plus and minus 10 m.y., respectively (in excellent agreement with U.S. Geological Survey K-Ar dating). Mineralization is present in the Dakota Sandstone, but whether the ore was syngenetic or epigenetic is unknown. Much of the stack ore was apparently formed during the Laramide orogeny about 60 m.y. ago, usually in close proximity to a redox front. Post-Laramide ore is proposed for several deposits in reduced ground at this redox front, some of which is apparently Tertiary although remobilized Jurassic ore cannot be distinguished from that from much younger sources even though reworked Jurassic ore is supported by high Sr 87/Sr 86 ratios. Ore possibly formed during the Tertiary from a southerly source for some deposits, and some remobilized ore, possibly of Pleistocene age, is known in minor amounts. (Auth)

<334>
Brookins, D.G., University of New Mexico,
Albuquerque, NM

Mechanisms for Uranium Deposition in Grants Mineral Belt. AAPG Bulletin 63(4):686-687. (1979, April)

A polygenetic model for uranium deposition of much of the ore in the Grants mineral belt results from (a) spatial relations of orebodies, (b) geochronologic studies, (c) clay-mineral studies, (d) trace-element studies, and (e) theoretical considerations. Trend ore apparently formed from southeast-flowing solutions entirely in reduced ground with organic carbon (plus some hydrogen sulfide) acting as reductant; this is supported by evidence for organic carbon in calcite penecontemporaneous with ore, trace-element distribution, and other factors. Uplift, remobilization, and reprecipitation of some of the stratigraphically high ore in the Laguna district is somewhat similar to Wyoming roll-type deposits in terms of mineralization control by sulfide-sulfate equilibria and clay-mineralogic variations. The effect of this event is not apparent in the deeper Ambrosia Lake ore. The Laramide orogeny resulted in the establishment of a redox front which, in turn, resulted in destruction and remobilization of some earlier trend ore and the formation of stack ore. Virtually all zones of rock weakness are subject to some mineralization near this front, and the sulfide-sulfate equilibria cause many of these stack deposits to resemble roll fronts. Roll geometry of some of this ore is due to encroachment of the front on reduced ground after the Laramide. Younger, but very local, solutions result in ore in oxidized ground, some of which is indicated by primary uranophane. Roll geometry is present for some of these deposits. The superimposition of the redox front on the older trend ore allows both carbon and sulfur to act as reductants, and orebody geometries are similar to Wyoming-type rolls in terms of uranium distribution but not necessarily for trace-element distribution. (Auth)

<335>
Childers, M.O., Western Standard Uranium,
Incorporated, Riverton, WY

Uranium Geology of the Kaycee Area Johnson County, Wyoming. Wyoming Sandstone, R.L. Enyert (Ed.), Proceedings of the 22th Field Conference, 1970. Wyoming Geological Association, Casper, WY, (pp. 13-30), 292 pp. (1970)

The stratigraphy, structure and regional geology of the Kaycee Area, Johnson County, Wyoming are described. The sands of the Wasatch and Fort Union formations, both Tertiary in age, are of major concern. Uranium and vanadium mineralization is well developed in the sandstones and conglomerates of these two formations. Brightly colored red deposits in both the Fort Union and Wasatch strata were caused by hematite staining in connection with their alteration as oxidizing waters carried uranium and vanadium through them. (MDW)

Cited as a reference in NURE Contractor Reports.

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GENESIS OF DEPOSITS

<336>
Coleman, R.G., USGS, Washington, DC

Mineralogical Evidence on the Temperature of Formation of the Colorado Plateau Uranium Deposits. Economic Geology 51(1):1-4. (1957, January)

The unoxidized uranium deposits on the Colorado Plateau are considered to represent primary ore that formed under equilibrium conditions, therefore minerals deposited by the primary ore fluids should exhibit properties inherent to existing temperature, pressure composition of these fluids during deposition. Uraninite, coffinite, low-valent vanadium oxides, and sulfides are the most abundant minerals deposited by the ore-forming fluids. The relative temperature of formation of the sulfides is discussed in the paper. It has been shown in equilibrium diagrams for the FeS-ZnS system that the formation temperature (ranging from 138-400 degrees C, when corrected for pressure) can be made on sphalerites known to have formed in the presence of excess iron sulfide. Sphalerites forming under these conditions are not common in the Colorado Plateau uranium Deposits, except in two Triassic sedimentary deposits containing ZnS that formed in the presence of excess iron sulfide. These are the Happy Jack Mine, White Canyon District, San Juan County, Utah, and the Hidden Splendor Mine, San Raphael District, Emery County, Utah. In both deposits yellow crystals of the sphalerite have formed concurrently with pyrite and uraninite. However, after the sphalerites were purified and anlayzed for the iron content, unit cell measurement were determined, and the temperature of formation was found to be less than 138 degrees C, the temperature at which the equilibrium diagram for Fe-ZnS is incomplete. Assumptions may be made as to the depositional environment (i.e., using geothermal gradient and lithiostatic pressure), knowing the time in which the sphalerites were deposited (Triassic-Jurassic), and these reveal that the primary uranium minerals are stable and could form at the temperatures indicated. (BBM)

<337>
Dubyk, W.S., and P. Young, Bendix Field Engineering Corporation, Grand Junction Operations, Grand Junction, CO

Preliminary Evaluation of the Uranium Favorability in the Kaiparowits Plateau Region, Garfield and Kane Counties, Utah. GJBX-64(78); 26 pp. (1978, May)

The report is a preliminary evaluation of the uranium potential of the basal sandstone of the Chinle Formation (Triassic) and of the Salt Wash Member of the Morrison Formation (Jurassic) in the Kaiparowits Plateau. Both subsurface and surface data were utilized, but due to limited outcrops, the Chinle Formation was studied principally by subsurface methods. Published and unpublished literature was searched to obtain information. Five surface samples were collected from the Morrison Formation. Vanadium, molybdenum, selenium, copper, iron, and lead were analyzed by atomic absorption spectroscopy and eU, eTh, and eK were determined by gamma-ray spectroscopy. Petrographic studies included clay analyses and mineral identification. Favorability of the basal Chinle sandstone was based on (1) presence of intermediate-size sandstone-filled channels cut into the Moenkopi, (2) presence of carbonaceous material, (3) an adequate source of uranium, and (4) gamma-ray anomalies from test-hole logs. Favorability of the Salt Wash Member of the Morrison Formation was based on (1) sandstone-mudstone ratios that approach equality, and (2) presence of thick sandstone lenses, carbonaceous material, and halos of light-tan to brown limonite staining. Although the basal Chinle sandstone and the Salt Wash Member of the Morrison contain sizable uranium deposits throughout much of the Colorado Plateau, both units lack characteristics that are favorable for significant uranium deposits in the Kaiparowits Plateau. (PAG)

Gamma-ray log from the area used for stratigraphic correlation and for identification of anomalies are listed in Appendix A. Appendix B contains sample description and analyses. Measured sections in the Kaiparowits Plateau and adjacent area are contained in Appendix C.

<338>
Galloway, W.E., Bureau of Economic Geology, Austin, TX

Deposition and Early Hydrologic Evolution of Westwater Canyon Wet Alluvial-Fan System. AAPG Bulletin 63(4):689. (1979, April)

The Westwater Canyon Member is one of several large, low-gradient alluvial fans that comprise the Morrison Formation in the Four Corners area. Morrison fans were deposited by major laterally migrating streams entering a broad basin bounded by highlands on the west and south. The Westwater sandstone framework consists of a down-fan succession of (1) proximal braided channel, (2) straight bedload-channel, (3) sinuous mixed load-channel, and (4) distributary mixed load-channel sandstone bodies. Regional sandstone distribution and facies patterns are highly digitate and radiate from a point source northwest of Gallup, New Mexico. Early groundwater flow evolution within the Westwater fan aquifer system can be inferred by analogy with Quaternary wet-fan deposits and by the interpreted paragenetic sequence of diagenetic features present. Syndepositional flow was controlled by the down-fan hydrodynamic gradient and high horizontal and vertical transmissivity of the sand-rich fan aquifer. Groundwater was abundant, fresh, and slightly alkaline; dissolution and transport of soluble humate would be likely. With increasing confinement of the aquifer below less permeable tuffaceous Brushy Basin deposits and release of soluble constituents from volcanic ash, flow patterns stabilized and relatively more saline, pregnant groundwater permeated the aquifer. Uranium mineralization occurred during this early postdepositional, semiconfined flow phase. Exposure, erosion, and possible further flushing of proximal fan deposits had little apparent effect on the quifer. Development of overlying Dakota swamps suggests a shallow water table indicative of regional discharge or stagnation. In either event, only limited downward flux of acidic water is recorded by local bleached, kaolinized zones where Westwater directly underlies the Dakota. Subsequent groundwater flow phases have further obscured primary alteration patterns and caused some local oxidation and redistribution of uranium. (Auth)

<339>
Gavasci, A.T., and P.F. Kerr, Columbia University, Department of Geology, New York, NY

Uranium Emplacement at Garnet Ridge, Arizona. Economic Geology 63(8):859-876. (1968, December)

Uranium-vanadium-copper minerals were found as a cement or as vein in the Navajo Sandstone, both along the contact with a breccia dike and nearby. The Navajo Sandstone exposed at Garnet Ridge is a fine-grained quartz arenite with subordinate microcline and altered plagioclase. Cement is scarce and where present it is mainly calcite. Near the dike the cementing materials become more abundant and numerous veins containing iron, copper, vanadium, and uranium minerals are present along cracks and fractures in the sandstone. Malachite, chrysocolla, calciovolborthite, tyuyamunite, limonite, chalcopyrite, and pyrite were identified in the veinlets or in the cement. It is believed that the breccia dikes and collapse structures at Garnet Ridge were probably formed as a result of intense gaseous activity at depth. The uranium, vanadium, and copper mineralization related to the breccia dikes suggests that metallic mineralization was associated with the formation of the dikes. Deposition of calcite as veinlets in the breccia shows that solutions migrated after the emplacement of the dike. The metallic mineralization probably occurred during the final hydrothermal stage of igneous activity. The types of garnets that occur at Garnet Ridge suggest a deep-seated origin and a medium- to high-grade metamorphism of the source rock. (JBT)

<340>
Germanov, A.I.

Geochemical and Hydrodynamic Conditions of Epigenetic Uranium Mineralization in Petroleum-Water Zones. Geochemistry 2:107-120. (1961)

The hydrodynamic conditions for the formation of uranium mineralization of the Ambrosia Lake type are considered. Epigenetic uranium mineralization arises in the marginal parts of petroliferous artesian basins. Where infiltrating ground water penetrates flooded petroleum reservoirs or rocks that formerly contained petroleum, the Eh of the water is lowered from 500-250 mv to as low as -400 mv, the dissolved components are rapidly reduced, and uranium is precipitated. Uranium enrichment of water in the oxidizing zone up to 5 x 10(E-6) or even n x 10(E-4) g/l is necessary for the formation of ore deposits. This is favored by warm or hot climatic conditions, under which soils enriched with supergene carbonates and sulfates are formed. In addition, the high clarke of uranium in rocks of the oxidizing zone [n x 10(E-3) percent and higher is favorable to uranium enrichment]. (Auth) (JBT)

<341>
Gott, G.B., D.E. Wolcott, and C.G. Bowles, USGS, Washington, DC

Stratigraphy of the Inyan Kara Group and Localization of Uranium Deposits, Southern Black Hills, South Dakota and Wyoming. USGS Professional Paper 763; 57 pp. (1974)

The Inyan Kara Group in the southern Black Hills consists of the Lakota and Fall River Formations of Early Cretaceous age. Uranium ore deposits are restricted to four stratigraphic units, of which only one is highly carbonaceous. These units are (1) the highly carbonaceous sandstones and siltstones of the lower unit of the Fall River Formation, (2) noncarbonaceous fluvial unit 5, also in the Fall River Formation, (3) noncarbonaceous fluvial unit 4, in the Fuson Member of the Lakota Formation, and (4) moderately carbonaceous fluvial unit 1 in the Chilson Member of the Lakota Formation. Uranium was introduced into the Inyan Kara with the artesian recharge of calcium sulfate type water from the Minnelusa. As this water migrated downdip, it was modified by ion exchange and sulfate reduction to either a sodium sulfate or sodium bicarbonate type water, causing an increase in pH values and a decrease in Eh values. Reduction of sulfate ions in the ground water was a major factor in creating a favorable environment for the precipitation of uranium. Other factors that affected the localization of the uranium deposits pertain to the concentration of metals in the ground water and to the rate of ground water flow. Oxidation of uranium deposits near the Inyan Kara outcrop may locally increase the concentration of uranium in the ground water and thereby increase the volume of uranium transported to the site of deposition. The distribution of the fluvial sandstones directly affects the rate of ground water flow and, therefore, the volume of transported uranium. (JBT)

<342>
Hoeve, J., Saskatchewan Research Council, Saskatoon, Saskatchewan

Classification of Uranium Deposits in Northern Saskatchewan. Uranium Deposits, Their Mineralogy and Origin, Short Course Handbook, Volume 3, M.M. Kimberley, (Ed.). University of Toronto Press, Toronto, Canada, Ch. 16, (pp. 397-402), 521 pp. (1978, October)

Uranium occurrences in northern Saskatchewan may be grouped into syngenetic and epigenetic types of deposits. Syngenetic deposits include both radioactive pegmatites and disseminations and local concentrations of uranium within Aphebian metasedimentary rocks of conglomerate types. The syngenetic deposits are of no present economic importance. The epigenetic deposits of northern Saskatchewan are represented by the well known Beaverlodge vein-type deposits and by the more important, and more recently discovered, unconformtiy-type of the Athabasca basin. Two episodes of epigenetic mineralization are believed responsible for these deposits. The first, of late Hudsonian age, is represented by the Beaverlodge vein-type deposits of simple mineralogy. The second episode is of approximately "Grenvillian" age and it gave rise to the unconformity-type deposits within the Athabasca basin. In the Beaverlodge area, this second episode led to reworking of Hudsonian mineralization in addition to generation of vein deposits of complex mineralogy. (JBT)

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GENESIS OF DEPOSITS

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Huffman, A.C., Jr., A.R. Kirk, and R.J. Corken, USGS, Denver, CO; Northern Arizona University, Flagstaff, AZ

Depositional Environments as Ore Controls in Salt Wash Member of Morrison Formation (Upper Jurassic), Carrizo Mountains, Arizona and New Mexico. AAPG Bulletin 63(4):689-690. (1979, April)

Uranium deposits in the Salt Wash Member of the Morrison Formation in the Carrizo Mountains area appear to be closely related to depositional facies. In the vicinity of the Eastside mines, southeastern Carrizo Mountains, the Salt Wash consists of a lower part, 10 to 15 m thick, and an upper part, 55 to 60 m thick. The lower part contains mudstone and silty sandstone interpreted as overbank and partially abandoned channel-fill deposits. It also contains a few large lenticular channel sandstones deposited by meandering and possibly braided streams. Uranium deposits are uncommon in the lower part. The upper part of the Salt Wash contains a much greater percentage of braided-stream-deposited channel sandstones, many of which coalesce to form prominent continuous ledges. The fines grained low-energy deposits are very limited in extent, commonly being less than 200 m long, 20 m wide, and 2 m thick. They have a lenticular cross section and a scour base. They consist of interbedded mudstones, claystones, and sandstones and are interpreted as abandoned and partially abandoned channel fills. Subsequent scouring of these beds has resulted in clay-clast conglomerates which were incorporated as lag deposits in the bases of overlying channel sandstones. Detrital organic debris is uncommon but is present in some channel-lag deposits as well as in some of the bedded mudstones. Uranium deposits in the Carrizo Mountains area are associated with abandoned and partially abandoned channel fill and with clay-clast lag conglomerates adjacent to major channel sandstone systems in the upper part of the Salt Wash. (Auth)

<344>
Johnson, C., Michigan Technological University, Department of Geology and Geological Engineering, Houghton, MI

Depositional Models and Areas Favorable to Mineralization. GJBX-42(76); Uranium and Thorium Occurrences in Precambrian Rocks, Upper Peninsula of Michigan and Northern Wisconsin, With Thoughts on Other Possible Settings, J. Kalliskoski, (pp. 143-159), 298 pp. (1976, June)

Primary mineralization accounts for the radioactivity observed in three places in northern Michigan. Although none of three prospects have economic potential, the processes which formed them could easily occur on a larger scale, and when this process is combined with supergene enrichment, economic concentrations could be formed. The syenite dike near Marquette represents the concentration of uranium and thorium by magmatic differentitation similar to but on a much smaller scale than the Ilimausaq complex in Greenland. The Greens Creek Pegmatite and the migmatite near Republic are interpreted to represent the reconcentration of uranium and thorium by metamorphism and recrystallization of an older rock. No syngenetic concentrations of uranium have been found in Michigan. The Goodrich conglomerate contains detrital grains of monazite, but only trace amounts of uranium. Supergene occurrences of uranium are the most prevalent type of uranium concentration in northern Michigan and the type of occurrence with the most economic potential. Three types of potential source rocks for the supergene occurrences are found in northern Michigan. They are pyritic black slates, granite gneisses, and rhyolites, all of which contain relatively high concentrations of syngenetic or primary uranium. Potential host rocks for supergene mineralization could theoretically include most rock types in the area. Proximity to the source rocks, the permeability and porosity of the rock, and a reduced chemical environment are required to fix uranium. Suitable host rocks include fractured and brecciated black slate; porous oxidized soft iron ore; vuggy, pyritic quartzite; diabase dikes, and shear zones and fractures in granites and gneisses. The mineralizing process requires a period of tectonic activity which produces openings in brittle rocks, followed by a period of intense chemical weathering. Two periods of tectonic activity have been recognized in Michigan. The most intense of these was the Penokean Orogeny dated at 1.9 b.y. The model "Lake Superior type uranium deposit" is a supergene concentration of uranium. Its occurrence is related to Middle Precambrian metasediments because of the ease with which uranium in black slates can be leached and reconcentrated. The deposits may thus occur within the black slates of within the stratigraphically underlying oxidized iron formation. The areas thought to have the highest potential for mineralization are those underlain by the black pyritic slates of the upper Marquette Range Supergroup. Also important, but less widespread are the supergene occurrences in fractured granites and felsites. (JWT)

GENESIS OF DEPOSITS

<345>
Kerr, P.F., Columbia University, Department of Geology, New York, NY

Criteria of Hydrothermal Emplacement in Plateau Uranium Strata. Peaceful Uses of Atomic Energy, Vol. 2, Survey of Raw Material Resources, Proceedings of the 2nd International Conference, Geneva, Switzerland, September 1-13, 1958. United Nations, New York, (pp. 330-334), 843 pp. (1958)

The Colorado Plateau has long been one of the major uranium producing provinces in the world. Opinions differ concerning the mechanism involved in the emplacement of Plateau ores, and four hypotheses now receive support: (1) the circulatory groundwater theory, (2) the ash-leach theory, (3) the syngenetic theory, and (4) the hydrothermal theory. Criteria applicable to the interpretation of origin include: (1) absolute age determination of primary uranium ores, (2) the evidence of wall rock alteration, (3) mineral and chemical associations of Plateau ores, (4) the role of organic matter in uranium emplacement, (5) the stratigraphic distribution of the ores, (6) the structural features associated with the ore-bearing solutions and (7) igneous and hydrothermal features near Plateau uranium deposits. These criteria tend to support the hydrothermal theory. The syngenetic theory assumes the uranium deposits are emplaced contemporaneously with the enclosing sediments. The mechanism of precipitation essentially is supergene, and deposits are formed at low temperatures. Criteria at variance with this theory are some of the absolute age data, alteration evidence, stratigraphic distribution, mineralization and hydrothermal features. Currently, this theory receives little attention. The ash-leach theory attributes the origin of Plateau uranium to supergene leaching from volcanic ash. Uranium deposits derived by leaching the overlying ash are believed by some to accumulate in underlying strata. This theory received strong support in the Wyoming area where early deposits were found stratigraphically below ash-bearing strata, but inherent weaknesses of this theory include absolute age data, hypogene mineralization, the role of organic matter, hydrothermal features, and the evidence of wall rock alteration. Also, sufficient uranium content in the ash remains to be demonstrated. Although certain local deposits may have formed by this mechanism, a general application of this theory seems unlikely. According to the circulatory groundwater theory, uranium deposits were emplaced in sediments by normal groundwater solutions. Groundwater circulation is assumed to have removed uranium ions from exposed areas of crystalline rocks and deposited repeated increments in the deposits as now found. The usual groundwater temperatures prevail, and igneous influence is absent. This theory is supported by the extensive evidence of wide lateral mineralization, the fact that uranium is precipitated from solution and the existence of a chemically feasible mechanisms of transfer. However, alteration, urano-organic ore deposition, and a number of aspects of the mineralization and igneous features of the Plateau fail to support the basement erosion as the primary source of uranium ions, and there is reason to believe that ores were frequently deposited at higher temperatures than prevail in normal groundwater. The hydrothermal theory envisages the source of uranium as magmatic fluids. The fluids, charged with uranium ions from primary magmatic sources, come in contact with precipitants. The precipitants such as plant detritus, petroliferous material, or accompanying sulfur compounds cause the deposition of uraninite, coffinite, or urano-organic compounds. The principal weakness of the theory lies in the limited extent to which supporting criteria have been fully studied and developed. Certain difficulties in absolute age determinations remain and problems concerning mineralization exist. (JBT)

<346>
Landwehr, W.R.

The Genesis and Distribution of Major Mineralization in Western United States. Economic Geology 63:967-970. (1968)

Major hydrothermal mineralization in the western United States has occurred in three epochs; Precambrian, Nevadamide, and late Tertiary. Probably in excess of 95 percent of the value of the metals produced has come from the Nevadamide deposits. The Nevadamide epoch is characterized by plutonism of two types; one giving rise to major mineralization and the other to little or none. Plutons of the first type are confined to the northeast trending belts of major mineralization. Plutons of the second type are well distributed over the entire region. Productive plutonism is the result of tangential tensional stress caused by regional uplift. Response to the stress has resulted in zones of crustal rupture that allowed the parental basaltic magma at depth to become mobile and ascend. During the ascent fractional crystallization and differentiation ultimately resulted in major mineralization. Barren plutonism is in part due to tangential compression stress, and in part to convectional temperature overturn. The plutons were formed by anatexis or granitization. (Auth) (JBT)

Cited as a reference in NURE Contractor Reports.

GENESIS OF DEPOSITS

<347>
Langford, F.F., University of Saskatchewan, Saskatoon, Saskatchewan, Canada

Stratigraphic Control of Uranium Deposits. AAPG Bulletin 63(4):690-691. (1979, April)

The restricted stratigraphic distribution of economic uranium deposits is one of their most consistent characteristics. Even the occurrence of uraniferous pegmatites in Saskatchewan and Ontario appears to have been stratigraphically controlled. Quartz-pebble conglomerate deposits are placers, but other deposits in sediments are chemical precipitates, characterized by thorium-free primary uranium minerals with vanadium and selenium. In marine sediments these minerals form low-grade, disseminated, widespread deposits that are obviously syngenetic. In terrestrial sediments, chiefly fluvial sandstones and associated vein deposits, the concentration of uranium varies widely, the high-grade portions constituting ore. Genesis is important in deciding how rigorously to limit exploration to certain stratigraphic situations. Genetic processes can only be inferred, but if deposits in diverse situations are compared, then features held in common are likely to be critical and others incidental. Thus vein deposits in Saskatchewan and Australia have common structural, mineralogic, and stratigraphic features, but differ in their basement host rocks. Their mineral assemblages, lack of zoning, and association with fluvial sandstones are also common to the Colorado-type sandstone deposits. The Wyoming type of roll deposit though in similar environments is unique, having mineralogic and compositional zoning, a feature of epigenetic deposits of other minerals and one which may be indicative of truly epigenetic origin. The hypothesis of near-surface, quasisyngenetic origin presumes that formations are unique at their time of formation, which explains the ubiquitous stratigraphic control. Objections to this hypothesis are based largely on the high temperatures and salinities indicated by fluid inclusions and the late dates given by Pb-U dating methods. However, these are the results of diagenesis which recrystallized the quasisyngenetic deposits at high temperature and produced discordant dates. In contrast, hypotheses that postulate ore formation long after deposition and burial of the sediments fail to account for the stratigraphic control. Unique features such as the presence of volcanic debris acting as an intrasediment source of uranium are commonly cited as ore controls, but only a very small proportion of sediments with such features has uranium deposits in spite of an apparent consistency of diagenetic processes. (Auth)

<348>
McMillan, R.H., Western Mines Limited, Toronto, Ontario, Canada

Genetic Aspects and Classifications of Important Canadian Uranium Deposits. Uranium Deposits, Their Mineralogy and Origin, Short Course Handbook, Volume 3, M.M. Kimberley (Ed.). University of Toronto Press, Toronto, Canada, Ch. 6, (pp. 187-204), 521 pp. (1978, October)

A classification of important uranium deposits which utilizes both genetic and descriptive criteria is presented. The uranium deposits are grouped in four major categories: (1) igneous; (2) metamorphic; (3) detrital; and (4) hydrogenic. With the Hydrogenic group are five sub-categories (1) hydrothermal; (2) syngenetic; (3) epigenetic; (4) syngenetic, supergene, and epigenetic; and (5) supergene. Uranium of igneous origin has been found in several alkaline and carbonatite complexes in the Canadian Shield and the Cordillera. Deposits of metamorphic origin include those which are found in fold belts where metamorphis has reached upper amphibolite to granulite grade. These deposits are of two main types: (1) felsic segregations consisting of pegmatitic or alaskitic sills and dikes, and (2) skarns. The most important detrital deposits are the paleoplacers in the Elliot Lake district. Of the hydrogenic deposits, those of epigenetic origin are the most important economically. These deposits include those hosted by continental sandstone and lignite, as in the Colorado Plateau and elsewhere in Tertiary basins of the United States, in addition to those in the Athabasca Formation of Saskatchewan. (JMT)

<349>
Miller, A.R., and A.N. LeCheminant, Canada Geological Survey, Ottawa, Ontario, Canada

Uranium Mineralization in the Baker Lake Basin, District of Keewatin. Proceedings of the Joint Annual Meeting of the Geological Association of Canada, the Mineralogical Association of Canada, and the Geological Society of America, Toronto, Ontario, October 23-26, 1978. The Geological Society of America, Boulder, Colorado, (p. 456), 531 pp. (1978)

Near Baker Lake, N.W.T., uranium mineralization occurs within Aphebian and Archean intrusive and gneiss complexes and unconformably overlying sedimentary and volcanic rocks of the Paleohelikian Dubawnt Group. Conglomerates and arkoses of the lower red bed sequence of the Dubawnt Group form overlapping fining-upward clastic wedges derived from a tectonically unstable region of sharp relief to the east and southeast. The red beds partly infill grabens and half-grabens. Subaerial potassic alkaline lavas, pyroclastics, and volcaniclastic sedimentary rocks overlie the red beds and locally extend over the basement outside the fault blocks. Small hypabyssal alkaline complexes and lamprophyre dykes intrude the basement and basal Dubawnt Group rocks and are temporally associated with alkaline volcanism. Three distinct uranium associations have been recognized: 1) fracture controlled mineralization in the Dubawnt Group and basement gneisses (Au-Ag-Cu-Se-U or Zn-Mo-Pb-Cu-U), 2) diatreme breccia mineralization in basement gneisses (Zn-Cu-U) and 3) impregnation and microfracture mineralization in altered arkose peripheral to lamprophyre dykes (Ag-Cu-U). Fracture controlled mineralization has structural characteristics and alteration mineral assemblages similar to hydrothermal vein deposits at Beaverlodge, Sask. Diatreme breccia mineralization results from hydrothermal systems channelled through porous highly brecciated gneiss. Mineralization within altered arkose formed by a two stage process. Fe and Cu sulphides and native Ag and Cu were deposited locally within thermal aureoles formed during emplacement of lamprophyre dykes. These mineralized zones subsequently provided the reducing environment for precipitation of uranium from groundwater. (Auth)

GENESIS OF DEPOSITS

<350>
Miller, T.P., and B. Johnson, USGS, Juneau, AK

An Occurrence of Parsonite, A Secondary Uranium Mineral, in Alaskite of the Wheeler Creek Pluton, Alaska. USGS OFR-78-315; 6 pp. (1978)

Parsonite, a hydrous phosphate of Pb and U, has been identified for the first time in Alaska, in the Purcell Mountains. The mineral occurs as a soft, yellow to chocolate coating closely associated with green muscovite on fracture surfaces in a shear zone in alaskite of the Wheeler Creek Pluton. The true width of the parsonite-bearing material in uncertain, but strong radioactivity has been detected over an area about 3m X 20m, with readings up to 10,000 cps being recorded. Coarse grained alaskite (radiometric age late Cretaceous) underlies the west end of Wheeler Creek pluton and intrudes lower Cretaceous andesitic volcanic rocks, upper Cretaceous rhyodacitic hypabyssal rocks, and upper Cretaceous quartz monzonite of the pluton. It is composed of K-feldspar, chiefly "patch" perthite with minor amounts of albite and abundant quartz. Biotite is the chief mafic mineral, with hornblende occurring locally near contacts with country rock; magnetite and allanite are accessory minerals. Scintillometer readings of 400-600 cps were obtained from the alaskite, while delayed neutron analysis of two samples showed 14.4 ppm and 13.4 ppm U and 52.3 ppm and 45.2 ppm Th. A sample of altered alaskite with a visible coating of parsonite and 4459 ppm U; a sample of altered alaskite without visible parsonite had 881 ppm U. The original source of U in the parsonite is unknown; occurrence of an oxidized U-mineral in association with a shear zone in uraniferous alaskite definitely represents secondary concentration of U. The parsonite may therefore indicate the presence of primary U-minerals and/or more widespread secondary enrichment of the alaskite. (LKB)

<351>
Borozenko, B.K., Leningrad Mining Institute, Leningrad, USSR

Uranium Metallogenic Epochs. International Geology Review 8(5):608-620. (1966)

No geologic era is characteristically uraniferous or characteristically barren on a world-wide scale. Beginning with the late Archean, commercial uranium deposits occur in all eras and their periods, thus there is no reason for preferential exploration in rocks of any particular period. Some eras (and periods) are more uraniferous than others with respect to certain large provinces and even continents. For instance, the bulk of the uranium reserves in Eurasia is represented by Paleozoic exogenous and endogenous deposits. The Mesozoic and Cenozoic come next in importance, followed by the Precambrian. In North and South America, Africa, and Australia, Proterozoic is most important; there are virtually no Paleozoic commercial deposits; and a considerable amount of uranium in Mesozoic and Cenozoic. The reasons for such a distribution are not clear. The great disparity between Paleozoic uranium reserves of America, Africa and Australia, on the one hand, and Eurasia on the other, is probably due to the difference in their respective tectonics. Uranium distribution within the Paleozoic section is very uneven, and there is a tendency for the exogenous mineralization to grow from the older periods to the younger. The opposite is true for endogenous mineralization. The uranium reserves grow smaller going from the older eras to the younger, but the picture is different if duration of eras is taken into account. As weighed for time, the reserves grow larger going from older to younger, both in their total and especially as regards to the exogenous deposits. This tendency is reversed for endogenous deposits. All eras, except the Paleozoic, show a preponderance of endogenous deposits over the exogenous and metasedimentary. The Paleozoic is somewhat richer in endogenous deposits. While the large granitic intrusions originated in the Archean and Proterozoic, the Proterozoic alone witnessed the origin of commercial high-temperature contact-metasomatic uranium skarn deposits. These deposits are scarce to nonexistent in post-Proterozoic times. The current view is that uranium is genetically related not to the large batholiths common in the Archean and Proterozoic, but rather to minor intrusions and subvolcanic formations. Such intrusions mark the late and terminal geosynclinal stages and they are typical of the subplatform and platform conditions. (JBT)

The report seems to be contradictory.

<352>
Nord, G.L., Jr., USGS, Reston, VA

Characterization of Fine-Grained Black Uranium Ores by Transmission Electron Microscopy. USGS Circular 753; Short Papers of the US Geological Survey Uranium-Thorium Symposium, 1977, J.A. Campbell (Ed.), (pp. 29-31), 75 pp. (1977)

Mineralogical and geochemical investigations of primary uranium minerals (uraninite and coffinite) and of the mechanisms by which these phases oxidize to the yellow uranyl minerals have been hampered by the fine-grained nature of the primary crystalline phases and the black amorphous colloidal nature of the products of the early oxidation steps. Because of this, the USGS has been employing a technique utilizing a transmission electron microscope (TEM) to study organic material containing fine-grained coffinite $[U(SiO_4)_{1-x}(OH)_{4x}]$ from the La Sal no. 2 mine in Mesa Co., Colorado. The coffinite-bearing material was made into a 20 micrometer-thick, doubly polished thin section, which was further thinned to electron transparency (1 micrometer) by argon ion milling. The scanning transmission electron microscope (STEM) showed the coffinite as elongated grains (1-2 micrometers wide and 10-15 micrometers long) filling collapsed plant-cell cavities in a carbonaceous matrix. At higher magnification, these grains appeared as aggregates consisting of individual crystals ranging from 30 to 500 nanometers in size embedded in the more transparent carbonaceous matrix. Covering the surfaces of the coffinite grains were 5- to 15-nanometer particles. These particles were found covering all coffinite grains observed, and were determined to be cubic with a unit cell edge of a=5.46 angstroms; a measurement consistent with unoxidized uraninite. The small uraninite particles were interpreted as reaction products from the breakdown of coffinite; the silica existing as an amorphous phase associated with the coffinite and the matrix. A thermal spike was probably the driving force in the reaction. This breakdown of coffinite to fine-grained uraninite plus silica may be a necessary step in the sequence by which coffinite oxidizes to the yellow uranyl minerals, reflecting the inability of the coffinite structure to accept the smaller hexavalent uranium atom and its charge-compensating defect. Alternatively, the uraninite may be the reaction product formed during the transformation of coffinite to a metamict state. (JMT)

<353>
Ojakangas, R.W., University of Minnesota, Department of Geology, Duluth, MN

Uranium Potential in Precambrian Rocks of Minnesota. GJBX-62(76); 259 pp. (1976, October)

Abnormally radioactive localities are present in the granites and pegmatites of the Northwest Angle, in the migmatites of the Vermilion granite-migmatite massif, in the McGrath Gneiss, and in the Thomson Formation. The highest radioactivity level measured was 1700 cps. Whereas the radioactivity at the first two locales mentioned above is apparently the result of igneous-metamorphic processes, the mineralization at the latter two may be related to unconformities. Moderate radioactivity levels were noted in some plutonic bodies as well. Lithologic, stratigraphic and structural relationships suggest that several sedimentary rock units, while not displaying abnormal radioactivity, should be favorable units in which to do further exploration. These are the Pokegama Quartzite, the Sioux Quartzite, the Puckwunge Formation, the Nopeming Quartzite, and the Upper Keweenawan formations. (Auth)(PAG)

<354>
Otton, J.K., USGS, Denver, CO

Geology of Uraniferous Tertiary Rocks in the Artillery Peak-Date Creek Basin, West-Central Arizona. USGS Circular 753; Short Papers of the US Geological Survey Uranium-Thorium Symposium, 1977, J.A. Campbell (Ed.), (pp. 35-36), 75 pp. (1977)

Uranium occurs in Tertiary rocks of the Artillery Peak-Date Creek basin 150 km northwest of Phoenix, Arizona. The Tertiary rocks within the basin consist of Eocene (?) sedimentary and intermediate to mafic volcanic rocks belonging to the Artillery Formation; lower Miocene silic volcanic and tuffaceous sedimentary rocks; upper lower to middle Miocene (?) mafic to intermediated rocks, coarse calstic rocks and tectonic breccias belonging to the Chapin Wash Formation; upper Miocene (?) basalt; and upper Miocene to Holocene sedimentary rocks. Facies relations within these units are complex, unconformites common, and no unit can be traced continuously throughout the basin. The rocks of the basin are generally tilted to the south or southwest and have been cut by normal faults. The predominant faults have a northwesterly trend, although east-west and northeast trending faults are also present. At the Anderson Mine in the eastern part of the basin, uranium occurs in silicified, tuffaceous, locally carbonaceous lacustrine mudstones, calcareous mudstones, and siltstones. These lacustrine and overlying fluvial rocks compose a unit that ranges in thickness from 60 to 120 m in surface exposures, and thickens considerably downdip to the south in the subsurface. Fossil plant material, consisting of thin beds of lignitic material and silicified twigs, leaves, and roots is abundant. Uranium occurs principally in thinly bedded siltstones rich in carbonaceous or silicified plant material. In many places these siltstones are highly stained by Fe- and Mn-oxides. Carnotite is the only uranium mineral yet identified, and it is probably secondary. The primary uranium phase has yet to be identified: in the mineralized carbonaceous rock it may by an urano-organic complex; and in the silicified rock it may be an urano-silica or urano-iron hydroxide complex. Interbedded with the mineralized tuffaceous siltstones are unmineralized, thickly bedded, greenish-gray tuffaceous mudstones, white to light-gray tuffaceous calcareous mudstones with abundant calcareous microfossils, and sparse sandstone and siltstone. A thin conglomerate is observed locally at the base. The overlying fluvial rocks consist of upward coarsening gray to greenish-gray sandstones and sandy conglomerates. Virtually the entire unnamed lower Miocene unit is rich in tuffaceous material and is anomalous in uranium content. Approximately 2 km west of Artillery Peak, uranium occurs in carbonaceous, calcareous siltstones and fine-grained sandstones immediately overlying the basal arkose of the Artillery Formation. The arkose overlies basement rocks which are rich in uranium and thorium in the Artillery Peak area. (JMT)

<355>
Pipiringos, G.N., and W.H. Denson, USGS, Denver, CO

The Battle Spring Formation in South-Central Wyoming. Wyoming Sandstone, R.L. Enyert (Ed.), Proceedings of the 22th Field Conference, 1970. Wyoming Geological Association, Casper, WY. (pp. 161-168), 292 pp. (1970)

Known uranium deposits in the Battle Spring formation are distributed in the Crooks Gap area in the northeastern part of the Great Divide Basin, Wyoming. Increased prospecting and mounting economic interest in the formation has been accompanied by uncertainty and confusion as to its physical and temporal limits. The purpose of the paper is to supply uranium exploration geologists and prospectors the criteria needed to reasonably ascertain the lithology stratigraphic limits and age of the formation, both surficially and subsurficially. The Battle Spring formation consists of arkose with lesser amounts of sandy siltstone and claystone. It is massive and crossbedded, friable, and weathers into featureless low hills and slopes. Loglike and spheroidal concentrations are common. The formation lacks recognizable discrete channel-sandstone bodies probably because it originated by the coalescing of piedmont alluvial fans along poorly developed drainage systems. Detrital coal, coaly trash, and poorly sorted carbonaceous siltstone beds are common which insure conditions suitable for host rock uranium deposits. The thickness varies from 3300 feet in its southern extent to 5000 feet in other parts. The age of the formation is now thought to be the entire lower Eocene. (NBW)

<356>
Provo, L.J., University of Cincinnati, Department of Geology, Cincinnati, OH

Stratigraphy and Sedimentology of Radioactive Devonian - Mississippian Shales of the Central Appalachian Basin. GJBX-37(77); COO-165C-1; 102 pp. (1976, December 31)

In eastern Kentucky and nearby, the Ohio Shale -- a radioactive, black organic-rich shale of Late Devonian age -- consists of two dominant lithologic types, which occur in a distinctive stratigraphic sequence. These 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 adjacent states. These seven units are the Cleveland Shale, Three Lick Bed, Upper, Middle, and Lower Huron Shales, Olentangy Shale, and Marcellus Shale. Black shale within the Ohio Shale in Kentucky typically contains 30 ppm uranium while lighter-colored, organic-poor shale contains only 15 ppm. Uranium content of samples from five stratigraphic subunits in Kentucky ranges from 6 to 74 ppm; average content is 27.7 plus or minus 3.2 ppm at 90 percent confidence limits. For all samples from Ohio, Kentucky, Tennessee, and Alabama, average uranium content is 32.9 plus or minus 3.9 ppm at 90 percent confidence limits, with the amount of uranium varying from 1 to 106 ppm. The amount of uranium varies with lithology and geographically. The samples richest in uranium are those black shales from Tennessee and Alabama. In Kentucky, the thickest, most uraniferous units are the Cleveland Shale and the Lower Huron Shale and the entire formation in the state is estimated to contain 6.28 x 10(E+12) tons of uranium. Black shales of Late Devonian age have a widespread geographic distribution in North America and on three other continents. The depositional settings of these black shales include: (1) shallow, cratonic seas, (2) distal facies of turbidites, and (3) basinal facies associated with reefs. The first two of these environments characterize the Ohio Shale and its equivalents in the central Appalachian Basin. (Auth)

This work was supervised by P.E. Potter, Professor of Geology and J.B. Maynard, Assistant Professor of Geology.

<357>
Rawson, R.R., Northern Arizona University, Flagstaff, AZ

Uranium in Todilto Limestone - Sabkha-Like Deposit. AAPG Bulletin 63(4):692. (1979, April)

The Todilto Limestone was deposited in or near a large lake that at times became restricted and evaporated to dryness. The formation has two members: a lower limestone and an upper gypsum member. The limestone member has been divided informally into three zones: the lower "platy" zone, a middle "crinkly" zone, and an upper "recrystallized" zone. The platy zone is interpreted to have been deposited below wave base under anoxic conditions. The crinkly zone has thin stromatolitic laminations and may form algal domes. The upper recrystallized zone appears in part to be a collapsed breccia caused by the removal of interbedded gypsum. Uranium ore is restricted primarily to the "crinkly" and recrystallized zones. These two zones may have been formed in a sabkha-like environment. A. R. Renfro has proposed a sabkha origin for some stratiform copper deposits. The same conditions that cause copper to precipitate would also cause uranium to precipitate. Groundwater bearing U+6 could be drawn upward by evaporative pumping through the decaying algal-mat zone where the uranium would be reduced to U+4 and precipitated. Carbonate materials lithify early destroying permeability so that uranium emplacement must occur before lithification. Radioisotope dates on uraninite in the Todilto Limestone indicate ore emplacement shortly after deposition. Uranium-bearing groundwater moved basinward in the underlying Entrada Sandstone and was drawn upward through the stromatolitic zones along the southwest margins of Lake Todilto and uranium was precipitated. (Auth)

<358>
Rimsaite, J., Canada Geological Survey, Ottawa, Ontario, Canada

Application of Mineralogy to the Study of Multi-Stage Uranium Mineralization in Remobilized Uranium Deposits, Saskatchewan. Uranium Deposits, Their Mineralogy and Origin, Short Course Handbook, Volume 3, M.M. Kimberley, (Ed.). University of Toronto Press, Toronto, Canada, Ch. 17, (pp. 403-430), 521 pp. (1978, October)

Mineralogical research provides the following data essential for the interpretation of radioactive anomalies as well as for evaluation and characterization of multi-stage mineralization of remobilized uranium deposits in northern Saskatchewan: a. identification and interpretation of the complex mineralogy of the ore and host rocks; b. paragenetic ralationships between uranium-bearing ore minerals and groundmass minerals; c. changing chemical and physical properties of the ore minerals and associated rock-forming minerals during superimposed alterations as a result of changing environmental conditions; d. chemical and structural relationship between primary and secondary ore minerals; e. mineralogical evidences of several periods of remobilization and redeposition of the mobilized uranium and radiogenic lead; and f. selection of minerals for age dating of multi-stage mineralizations and alterations that have recurred during a time period of at least 1800 million years. The assessment, characterization and exploitation of a uranium deposit is difficult without pertinent mineralogical background data. (Auth)

<359>
Robertson, J.A., Ontario Geological Survey, Room 911, 77 Grenville Street, Toronto, Canada

Uranium Deposits in Ontario. Uranium Deposits, Their Mineralogy and Origin, Short Course Handbook, Volume 3, M.M. Kimberley, (Ed.). University of Toronto Press, Toronto, Canada, Ch. 9, (pp. 229-280), 521 pp. (1978, October)

Ontario presently has two uranium mining camps: Elliot Lake and Bancroft. These deposits host about 13 percent of the free world's identified and partially identified uranium resources in the economic and subeconomic categories, having over 430,000 metric tons of uranium. The uranium ores, particularly those from Elliot Lake, also contain substantial resources of thorium. In addition to these deposits, the Province of Ontario hosts a number of other uranium deposits. The geology of Ontario and the nature and distribution of the uranium deposits are summarizied in this review. (JHT)

<360>
Rosholt, J.N., and A.J. Bartel, USGS, Denver, CO

Uranium, Thorium, and Lead Systematics in Granite Mountains, Wyoming. Earth and Planetary Science Letters 7:141-147. (1969)

Comparisons of radiogenic lead with uranium and thorium in whole-rock samples of granite from the Granite Mountains indicate that lead and thorium behaved as closed systems, but uranium did not. The usually low U-238/Pb-204 ratio values, coupled with the radiogenic Pb-206/Pb-204 ratios, indicate that uranium contents were once considerably greater than those present in the surface rocks today. The data obtained on the uranium-thorium-lead system also indicate that many of the rocks in this granitic unit originally had Th/U ratios of less than one. The most feasible interpretation is that the uranium was leached from the near surface rocks at some time during the Cenozoic, providing a major source for the uranium deposits in the central Wyoming sedimentary basins. (JHT)

<361>
Ruzicka, V., Canada Geological Survey, Ottawa, Ontario, Canada

Phaneroizoic Uranium Deposits and Occurrences in Europe and Eastern North America. Uranium Deposits, Their Mineralogy and Origin, Short Course Handbook, Volume 3, M.M. Kimberley. (Ed.). University of Toronto Press, Toronto, Canada, Ch. 8, (pp. 217-228), 521 pp. (1978, October)

Most European vein-type and related uranium deposits occur in the Hercynian orogenic belt. The Hercynian orogeny affected the Paleozoic and Precambrian complexes in a belt stretching from the Iberian Peninsula through France, Germany, and part of eastern Europe. Subdivision of the Hercynian orogenic belt into local zones is based both on variable proportions of pre-Hercynian rocks and on regional variations in the style of Hercynian deformation. The Moldanubian zone is the richest in vein-type and related uranium deposits. The backbone of this zone is the Hercynian cordillera which extends from the Iberian Meseta through the Armorican Massif, the Massif Central, the Black Forest, and through the Bohemian Massif. Uranium reserves are roughly proportional to grade of metamorphism through the zone and two types of deposits occur: (1) intragranitic veins and (2) deposits in peribatholithic shale, schist, and paragneiss. Sedimentary uranium deposits in Europe are spatially related to platforms. The cover rocks on Hercynian and Alpine basements host several deposits in sandstone and a large deposit in Cambrian alum shale is known from the Ranstad area in Sweden. Most volcanic associated uranium resources in Europe are related to Carboniferous and Permo-Triassic volcanic activity and are spatially restricted to areas in the western Carpathians of Czechoslovakia, to the northern Italian Alps, and to the area between Dinarides and the Serbo-Macedonian Massif. Conceptual genetic models based on uranium deposition in Europe are applicable to exploration in similar geological environments in eastern North America. The Appalachian orogeny contains several potentially favorable rock types. (JHT)

<362>
Shelby, C.A., Bureau of Economic Geology, Austin, TX

Heavy Minerals in the Wellborn Formation, Lee and Burleson Counties, Texas. University of Texas Report of Investigations 55; 54 pp. (1965, April)

At five places along the outcrop of the Wellborn Formation in Lee and Burleson counties, Texas, anomalously high gamma radiation is associated with concentrations of heavy minerals. The most abundant heavy minerals are ilmenite, magnetite, and zircon. The radiation is emitted by some radioactive element in zircon. The intensity of the radiation and the areal extent of the radiation anomalies were measured by a scintillation counter. The Wellborn Formation, composed of sediments deposited in near-shore environments, is characterized by cross-bedded sandstones lentils interbedded with montmorillonitic, lignitic shale and lignite. Heavy minerals in the lower part of the Wellborn are concentrated in thin sheets and wedges along cross-beds and in local patches and streaks. There are about 4 million tons of heavy mineral-bearing sandstone with an average of about 2 percent heavy minerals, or 2-1/2 million tons with an average of almost 3 percent heavy minerals. Locally, ilmenite, magnetite, and zircon make up as much as 25 percent of the sandstone, although concentrations are too small to be considered as commercial deposits under present economic conditions. (Auth)

Cited as a reference in NURE Contractor Reports.

<363>
Staatz, M.H., and F.W. Osterwald, USGS, Denver, CO

Geology of the Thomas Range Fluorspar District, Juab County, Utah. USGS Bulletin 1069; 97 pp. (1959)

The Thomas Range fluorspar district covers an area of around 34 square miles surrounding Spor Mountain in central Juab County. From its discovery in 1943 to the end of 1952, 12 properties in this district yielded a total of 75,312 short tons of fluorspar. Almost all of the fluorspar deposits have an abnormally high uranium content. All but 1 of the 7 fluorspar veins and pipes that contained over 0.050 percent uranium are on the southern end of Spor Mountain. Analyses of 155 fluorspar samples revealed a range of from 0.003 to 0.33 percent uranium. The highest grade uranium samples came from the Bell Hill, Harrisite, Eagle Rock, Lucky Louie, and two smaller prospects. Most of the deposits are enriched in uranium near the surface. This is believed to have been effected in an arid climate by slow leaching of the upper part of the ore body, in part by material being actively eroded. The uranium was redeposited a few inches to 30 below the rock from which it was leached, owing probably to the adsorption of the ground water by the dry underlying ore. The uranium content from upper workings may be as much as twice that at depth. (JHT)

Cited as a reference in NURE Contractor Reports.

<364>
Steacy, H.R., and S. Kaiman, Canada Geological Survey, Ottawa, Ontario, Canada; Canada Centre for Mineral and Energy Technology, Ottawa, Ontario, Canada

Uranium Minerals in Canada: Their Description, Identification and Field Guides. Uranium Deposits, Their Mineralogy and Origin, Short Course Handbook, Volume 3, M.M. Kimberley (Ed.). University of Toronto Press, Toronto, Canada, Ch. 4, (pp. 107-140), 521 pp. (1978, October)

The mineralogy of uranium, particularly within Canada, is discussed in this chapter. The uraninite group of minerals, along with brannerite, uranothorite, thucholite, and coffinite are covered in some detail. In addition, sections on secondary uranium minerals, uranium in accessory minerals, and mineral identifications are included, as well as an extensive table listing all known uranium minerals and their compositions. (JHT)

<365>
Theis, N.J., David S. Robertson and Associates Limited, 20th Floor, 65 Queen Street West, Toronto, Ontario, Canada

Mineralogy and Setting of Elliot Lake Deposits. Uranium Deposits, Their Mineralogy and Origin, Short Course Handbook, Volume 3, M.M. Kimberley, (Ed.). University of Toronto Press, Toronto, Canada, Ch. 13, (pp. 331-338), 521 pp. (1978, October)

The quartz-pebble conglomerates of the Elliot Lake-Blind River and Agnew Lake areas are the most important source of uranium in Ontario. The uranium-bearing quartz-pebble conglomerates are confined to the Matinenda Formation which lies at the base of the Huronian Section. The mineralogy of these quartz-pebble conglomerates is directly related to the depositional energy environment. It changes in response to changes in depositional conditions. Minerals, such as pyrite, which have a large range of grain sizes, reflect depositional environment by corresponding changes in grain size. Minerals with a limited size range, such as uraninite, monazite, and zircon reflect depositional energy conditions by changes in their concentrations. There has been some redistribution of uranium onto titania collectors, but this has not changed the placer nature of the ore reefs. (JHT)

<366>
Thurston, W.R., M.H. Staatz, and D.C. Cox, USGS, Denver, CO

Fluorspar Deposits of Utah. USGS Bulletin 1005; 53 pp. (1954)

The studies of fluorspar localities in Utah made by the U.S. Geological Survey during and since the recent war are summarized. The fluorspar at the Cougar Spar and Blue Bell mines in the Indian Peak Range of western Beaver County occurs as fissure veins in fault and breccia zones in volcanic and intrusive rocks. At the Monarch (Staats) claims in west-central Beaver County fluorspar was mined chiefly from a fault between limestone and rhyolite porphyry. The Thomas Range district in Juab County has yielded sizeable tonnages of fluorspar from pipes in faulted dolomite and rhyolite porphyry. From 1918 to 1924 the Silver Queen mine in Tooele County produced fluorspar from fissure veins in faulted limestone. The report describes the geology of producing mines and the various prospects examined. Production and reserves of fluorspar for Utah are summarized. (Auth)

<367>
Tremblay, L.P., Canada Geological Survey, Ottawa, Ontario, Canada

Geologic Setting of the Beaverlodge-Type of Vein-Uranium Deposits and its Comparison to that of the Unconformity-Type. Uranium Deposits, Their Mineralogy and Origin, Short Course Handbook, Volume 3, M.M. Kimberley, (Ed.). University of Toronto Press, Toronto, Canada, Ch. 18, (pp. 431-456), 521 pp. (1978, October)

The rock succession in the Beaverlodge area is comprised of four main components: Tazin Group, Martin Formation, Athabasca Formation, and gabbro dikes. The Tazin group is at the base of the succession and it is overlain unconformably by the Martin Formation, and locally by the Athabasca Formation. The Martin and Athabasca Formations do no occur in contact, but from geological considerations, the Athabasca is assumed to be the younger. Gabbro dikes cut Tazin rocks, part of the Martin Formation, and the Athabasca Formation south of Lake Athabasca. There are three distinct types of uranium deposits in the area: syngenetic, epigenetic, and supergene. The syngenetic deposits are represented by remnants of the country rock richer in radioactive minerals than the enclosing granitic rocks, by granitic areas slightly more radioactive than most, and by radioactive coarse-grained pegmatites. These deposits are not economic and in general have some thorium and rare earths in addition to uranium. Their main radioactive minerals are uraninite, monazite, zircon, and uranothorite. The supergene deposits are characterized by the secondary minerals; uranophane, liebigite, kasolite, fourmarierite, zippeite, and several others of lesser importance. These deposits are small and are restricted in their distribution to the present day surface and appear to have formed recently. The epigenetic deposits are the most common and constitute the largest known deposits in the area. Pitchblende is their main uranium mineral and these deposits have no thorium and rare earths. Most of the pitchblende is colloform and massive. The epigenetic deposits occur mainly as veins and disseminations and, based on their mineral assemblages, can be classified into two distinct groups. The most important group is characterized by a simple mineral assemblage, the main minerals being pitchblende, hematite, and pyrite. The other group constitutes only rare economic deposits. It has a complex mineralogy, having, in addition to pitchblende, hematite, and pyrite, fair amounts of sulfides, arsenides, etc. of Ni, Co, Bi, and some gold and silver. (JMT)

<368>
Truesdell, D.B., and R.C. Zollinger, Bendix Field Engineering Corporation, Grand Junction Operations, Grand Junction, CO

Preliminary Study of the Uranium Potential of the Triassic-Jurassic Basin in Connecticut and Massachusetts. GJBX-68(77); 20 pp. (1977, October)

Possible uranium source rocks are found in both the eastern and western highlands bounding the Connecticut Basin. They include pre-Triassic schists, gneisses, granites, and pegmatites. Within the Connecticut Basin, possible source rocks include the Granby Tuff and Hitchcock pyroclastics, which are associated with the Hampden and Holyoke basalts in southern Massachusetts. Results of analyses show that these rocks are favorable as potential uranium sources. Interbedded and intertonguing sandstone, mudstones, and shales are common throughout the Connecticut Basin. Fossil plants and organic carbon sufficient to create a reducing environment occur in all sedimentary units, particularly in the black shales of the Shuttle Meadow and East Berlin Formations. Although faults, which may form impermeable barriers to circulating mineralizing fluids, are distinguished throughout the basin, they are concentrated around New Britain and along the eastern and western borders. The Mount Carmel, West Rock, and Barndoor Sills form barriers to permeability in the central and southern portions of the Hartford Basin. Permeability traps also occur where channel sands pinch out and facies changes occur in alternating sandstones and shales. No anomalous uranium concentrations were detected with the exception of the gray sandstones mapped as the Lower Shuttle Meadow Formation in the vicinity of the Newgate Prison Mine. Here, uranium is associated with copper directly below an unconformity. Gamma spectrometric, fluorometric, and atomic analyses suggest a correlation between uranium and copper, but no relation between uranium and copper minerals can be seen. Disequilibrium shown by some of the analytical data suggests that the uranium may have been leached and redistributed within the sandstone. (PAG)

<369>
Tugarinov, A.I., I.L. Khodakovskiy, and A.P. Zhidikova, Academy of Sciences, V.I. Vernadskii Institute of Geochemistry and Analytical Chemistry, Moscow, USSR

Physicochemical Conditions for Molybdenite Production in Hydrothermal Uranium-Molybdenum Deposits. Geochemistry International 7-8:731-739. (1974, July)

The physicochemical conditions characteristic of the hydrothermal solutions that produce uranium-molybdenum deposits are discussed. The transport conditions are considered for Mo(IV) in hydrothermal solutions containing fluoride, thiomolybdate, and uranium molybdenum coordination compounds. It is found that the Mo and U can be transported simultaneously as hexavalent compounds in the presence of small amounts of hydrogen sulfide [about 10(E-7) M] at about 150 degrees C. Molybdenite and uranium minerals can crystallize together when the elements are reduced to the tetravalent state. (Auth) (JMT)

GENESIS OF DEPOSITS

<370>
White, M.V., and R.F. Martin, Gulf Minerals Canada Limited, Toronto, Ontario; McGill University, Department of Geological Science, Montreal, Quebec, Canada

Felsic Volcanism within the Aillik Series, Labrador, and Associated Uranium Mineralization. Proceedings of the Joint Annual Meeting of the Geological Association of Canada, the Mineralogical Association of Canada, and the Geological Society of America, Toronto, Ontario, October 23-26, 1978. The Geological Society of America, Boulder, Colorado, (p. 515), 531 pp. (1978)

> The Aillik Series comprises a metamorphosed sequence of Paleohelikian rhyolite flows and pyroclastic units, less extensive tholeiitic and alkaline basaltic flows and related subvolcanic intrusive and metasedimentary rocks. The volcanic suite displays bimodality and trends of iron enrichment and alkalinity characteristic of products of ensialic rift systems. Differentiation trends, field associations and a low initial Sr 87/Sr 86 of 0.704 imply a comagmatic origin for the felsic volcanic and intrusive rocks and an ultimate mantle source with minimal crustal contamination. Numerous uranium showings occur mostly associated with felsic differentiates; those of economic interest are found within porous zones where leaching and pronounced hydrothermal Na-for-K exchange and Na-enrichment are evident. An ultimate hydrothermal source for the uranium in synvolcanic fluids is proposed; subsequent groundwater circulation may well account for remobilization of the uranium, possibly as chloride complexes, and local enrichment into zones of economic significance. (Auth)

<371>
Federal Water Pollution Control Administration, Cincinnati, OH

Radium 226 and Radon 222 Concentrations in Central Florida Ground Waters. PB-260 211; 37 pp. (1966, January)

In central Florida, 105 water wells were sampled for Rn 222 and Ra 226 by the FWPCA at the request of the Florida State Board of Health. Sampling was carried out to measure ground water contamination by radionuclides released by mining of U-bearing phosphate deposits, fertilizer spoil piles, and waste water ponds. Phosphate is mined from the Bone Valley Formation (Pliocene), which is derived from and underlain by the Hawthorne Formation (Miocene). The Hawthorne is the confining layer for the principal artesian aquifer of central Florida; the top of the aquifer is in the Tampa Limestone (Miocene). Local recharge occurs where sinkholes penetrate the Hawthorne; these may also act as access routes for pollutants. Radon concentrations ranged from 23-46,600 pCi/l and radium from 0-76 pCi/l; means were 1860 and 1.2 pCi/l, respectively. A correlation exists between Rn and Ra concentrations, but cannot be defined at present. Analyses for U, Th, Pb 210, Po 210, and certain inorganic compounds were performed on selected samples. Two municpel water supplies and 12 private wells exceeded the 3 pCi/l Public Health Service drinking Water Standard for Ra 226. 3 wells were greater than 10 pCi/l, one being used by a food processing plant. (LKH)

<372>
Baillieul, T.A., and G.J. Indelicato, Bendix Field Engineering Corporation, Grand Junction Operations, Grand Junction, CO

Uranium in the Glen Wild Area, Woodridge, New York, 7.5-Minute Quadrangle. GJBX-86(78); 15 pp. (1978, November)

Uranium occurrences at five localities in a sequence of alternating channel sands and mudstones of the Upper Devonian Catskill Formation are described. The largest occurrence known, at Gibber Egg Company, is about 200 feet long and, in places, more than 1 foot thick. The calcium-uranium silicate uranophane has been identified at one locality, and secondary copper minerals have been identified at three other localities. Chemical U308 assays as high as 9980 ppm were recorded. The reconnaissance indicated that the rocks of the Glen Wild area belong to the upland alluvial-fan-and-braided-stream association which places the region very close to the sediment source. Two possible mechanism for the uranium concentrations are given: (1) Diagenetic Model and (2) Syngenetic Model. In the former, uranium ions are absorbed on the surface of clay particles and carried in the suspended load to be deposited with red muds. During burial and diagenesis the muds are compacted and liberate water. Under appropriate Eh and pH conditions uranium is released from the clay and goes into solution. Water saturated in uranium then migrates through the muds to a conglomeratic channel, which acts as a conduit for ground water, and is carried to a concentrating point. In the syngenetic model, uranium-saturated ground waters enter the system from an outside source, presumed to be a metamorphic terrain to the east exposed during Devonian time. The fluids travel most readily through the coarser conglomeratic layers and are stratigraphically bound by the less-permeable red mudstones. In both models, organic debris is the most likely reductant and fixing agent for the uranium. (JMT)

<373>
Barlow, J.L., AEC, Salt Lake City, UT

Some Uranium Occurrences in Northern Ferry County, Washington. RME-2068; 22 pp. (1958, October)

Prospecting for uranium in northern Ferry County, Washington, was most intense during the summer months of 1955 and 1956. The principal host rocks for the uranium minerals are bodies of pegmatite that occur as segregations with a batholithic mass, and as injections into older metamorphic rocks. Uranium was concentrated in residual fluids during late-stage consolidation of the magma, and crystallized as uraninite and uranium-bearing refractory minerals at approximately the same time as the essential mineral constituents of the pegmatite. Some of the uranium was subsequently taken into solution by ground waters, transferred short distances, and recrystallized as secondary uranium minerals in interstitial spaces and along parting surfaces. Minor amounts of uranium occur in the intruded rocks but usually are confined to zones located near the contact with a pegmatite body. The uraniferous pegmatites appear to be typically lens-like and pinch out with short distances. The uranium minerals are erratically distributed throughout the pegmatites and, when concentrated in ore-grade deposits, they are usually confined to small, discontinuous zones. Several stockpiles containing a maximum of 150 tons of uraniferous material have been collected throughout the district; none are considered of ore grade under current marketing conditions. Small tonnages of commercial-grade uraniferous material could be extracted at many of the prospects by very selective mining. (JMT)

<374>
Berthoud, E.L.

On the Occurrence of Uranium, Silver, Iron, et cetera in the Tertiary Formation of Colorado Territory. Natural Sciences of Philadelphia 27:363-366. (1875)

A mineral vein found six miles north of Golden, Colorado at the Lyden Coal mine was geologically investigated and analyzed. The host of the vein was a sandstone containing clay and clay shale. There was little alteration observed in the host rock in the vicinity of the vein. The vein was found to contain from .2 to 2 per cent uranium. (JMT)

<375>
Butler, A.P., Jr., and R.P. Fisher, USGS, Denver, CO

Uranium and Vanadium Resources in the Moab 1 Degree x 2 Degree Quadrangle, Utah and Colorado. USGS Professional Paper 988-B: 22 pp. (1978)

The Moab quadrangle of Utah and Colorado has several very productive uranium and uranium-vanadium deposits and a significant resource potential. Rocks exposed over most of the quadrangle consist of bedded sedimentary rocks of Paleozoic and Mesozoic ages. The Chinle Formation of Triassic age and the Morrison Formation of Jurassic age contain most of the known uranium deposits. The primary ore minerals in the deposits consists of uranium and vanadium oxides and silicates, which mainly impregnate the sandstones. Tabular orebodies that average somewhat less than a meter thick and are as much as one hundred meters across are characteristic. Generally, these bodies lie nearly parallel to the bedding of the host sandstone, and they are mainly localized by sedimentary structural features. These deposits are believed to have been formed by ground waters moving along the beds before the host beds became deeply buried. Most of the deposits in the Chinle Formation are in the Big Indian mineral belt on the southwest side of the Lisbon Valley anticline. These deposits have yielded ore containing uranium worth about $500 million. Favorable locations for similar deposits may be on the flanks of the Dolores anticline and possibly on the flank of the Moab anticline and ground bordering the southwest side of Spanish Valley. Deposits in the Salt Wash Member of the Morrison Formation have yielded approximately 9,100,000 metric tons of ore from which more than $600 million worth of vanadium and uranium has been extracted. More than 80 percent of this ore came from the Uravan mineral belt. The belt was probably localized along the toe of a subsidiary alluvial fan, which was formed by a distributary stream system on part of the main fan in an area of minor subsidence during Salt Wash time. The deposits in the belt and on the mid-slope of the fan west of the belt occur in sandstone lenses that formed along the courses of the major distributary streams; deposits outside the area of this alluvial fan also occur in sandstone lenses formed in major stream courses. The ore deposits are believed to have formed before burial by marine sedimentary beds in Late Cretaceous. Reserves plus undiscovered resources in deposits in the Uravan mineral belt probably contain about 12,700 metric tons of U308; those in the fan area west of the belt about 7,900 metric tons of U308; and those in the Salt Wash in other parts of the quadrangle about 3,400 metric tons of U308. (Auth) (JMT)

<376>
Coleman, R.G., AEC, Division of Raw Materials, Washington, DC

Mineralogical and Geological Investigations of the Uranium Deposits of the Wind River District, Wyoming. RME-4056; 25 pp. (1954, June)

The study of the uranium deposits of the Wind River District, Wyoming, was undertaken to determine the relationships between the mineralogy and uranium equilibrium state and the field geology of the deposits. The uranium deposits of the Wind River Basin appear to follow a sequence according to their relative position with regard to the groundwater table or erosional benches. The analytical and geological data strongly suggest that the cap rock is the source rock for the higher grade mineralized areas. High arsenic content in most of the uranium-bearing cap rock localities strongly suggests a hydrothermal source of uranium. The concentrations of yellow to green secondary uranium minerals are found at various stratigraphic horizons and show considerable mineralogical variation. All exposures examined indicate that the mineralized areas are small and irregular. In exposures examined in detail, the brownish cap rock overlies the mineralized areas. In some localities, secondary uranium minerals are present in the cap rock also, where they have been produced as a result of alteration of the brown interstitial material by leaching. The host rock in the mineralized areas is quite variable, grading from clay (shale) through fine to coarse sandstone; very commonly, uranium minerals are found in the boulder conglomerate lenses. Two distinctly different types of uranium mineralization can be distinguished in the field which suggest that these deposits may have been formed in several ways. (JMT)

<377>
Dahlkamp, F.J.

Classification of Uranium Deposits. Mineralium Deposita 13(1):83-104. (1978)

A listing of the recognized types of uranium mineralization shows nineteen determinable types out of which only six are of economic importance at present: Oligomictic quartz pebble conglomerates, sandstone types, calcretes, intra-intrusive types, hydrothermal veins, and veinlike types. The different types can be genetically related to prevalent geological environments: (1) the primary uranium occurrences formed by endogenic processes; (2) the secondary occurrences derived from the primary by subsequent exogenic processes; and (3) the tertiary occurrences, which are believed to be formed by endogenic metamorphic processes. Little is known about the behavior of uranium during metamorphosis, and thereby the metallogenesis of the tertiary uranium generation is still vague. A metallotectonic-geochronologic correlation of uranium depsotis shows that a distinct affinity of the uranium exists to certain geologic epochs: to the Upper Archean-Lower Proterozoic, to the Hercynian and in a less established stage, to the Upper Proterozoic. (Auth) (JMT)

<378>
De Lora, F., Direccion de Plantas Pilota e Industriales, Junta de Energia Nuclear, Madrid, Spain

Investigations on the Nature and Physical Concentrations of Spanish Uraniferous Quartzites. Processing of Low-Grade Uranium Ores, Proceedings of a Panel, Vienna, June 27 - July 1, 1966. International Atomic Energy Agency, Vienna, (pp. 143-156), 257 pp. (1967)

A study of a radioactive material from Santa Elena is presented. The material contained over 130 ppm U_3O_8, 600 ppm ThO_2, 4.9 percent ZrO_2, and 14.29 percent TiO_2. Over 150 million tons of the material were examined and in the light of these studies, the material was defined as a rutile-zirconiferous quartzite with a double radioactivity source due tot he uranium enclosed in the zircon lattice structurre and to the presence of monazite. No brannerite or davidite was present in the material, and there was no conclusive evidence of the presence of sphene. (Auth) (JMT)

<379>
Dickinson, K.A., USGS, Denver, CO

Detailed Stratigraphy and Sedimentology of Whitsett Formation in Uranium Area of Western Karnes County, Texas. AAPG Bulletin 63(3):440. (1979, March)

The Whitsett Formation of the upper Eocene Jackson Group contains, in ascending order, the Dilworth Sandstone, Conquista Clay, Deweesville Sandstone, Dubose, Tordilla Sandstone, and Fashing Clay Members. In Atascosa to McMullen Counties, the Callihan Sandstone Member, considered to be a stratigraphic equivalent of the Tordilla, is apparently the same age as the Fashing. The Deweesville is called the Stones Switch Sandstone Member by some geologists. The Fashing contains flood-plain, lagoon-bay, and distributary-channel facies. The Kellner and Rosenbrock uranium mines are in the distributary-channel facies of the Fashing. These mines have previously been considered to be in the Tordilla Sandstone Member. The Callihan Member apparently represents tidal-delta sandstone at its type locality. The Tordilla is a transgressive barrier-beach unit in the areas of the Pfiel-Wright and Weddington-Butler-Galen-Sickenius uranium-ore trends. Farther east, in the Hanka and Stoeltje uranium mines, the Tordilla is represented by a back-barrier island facies. Although the predominant facies of the Dubose is paludal and bay-lagoon mudstone, the ore in the Lauw and Bieker uranium mines is in a sand-filled distributary-channel facies. A back-beach facies of the Deweesville contained the ore of the Search mine, and the F. Brysch mine is in the lower of two beach units in the Deweesville. The sandstone members of the Whitsett Formation were deposited in transgressive barrier beaches, although locally they may be represented by progradational beaches or tidal inlets and deltas. Sandstone deposited in the distributary channels is equivalent in age to the clay members. The grains of the sandstone units in the Whitsett are composed mostly of feldspar and quartz. Some facies also contain abundant volcanic shards. Montmorillonite and clinoptilite and part of the feldspar are authigenic constituents in the sandstone. The sandstone of the distributary channels is coarser grained than that in the beach sequences. (Auth)

<380>
Dunham, R.J., USGS, Washington, DC

Uranium Minerals in Oligocene Gypsum Near Chadron, Dawes County, Nebraska. TEI-525; 31 pp. (1955, May)

Carnotite, sabugalite [$HAl(UO_2)_4(PO_4)_4$-$16H_2O$], and autunite occur in the basal 25 feet of a 270-foot sequence of nonmarine bedded gypsum and gypsiferous clay in the Brule Formation of Oligocene age about 12 miles northeast of Chadron in northeast Dawes County, Nebraska. Uranium minerals are visible at only two localities and are associated with carbonaceous matter. Elsewhere, the basal 25 feet of the gypsum sequence is interbedded with carbonate rocks and is weakly but persistently uraniferous. Uranium probably was emplaced from above by uranyl solutions rich in sulfate. (Auth)

<381>
Falkowski, S.K., New Mexico Institute of Mining and Technology, Socorro, NM

Geology and Ore Deposits of Johnny M Mine, Ambrosia Lake District, New Mexico. AAPG Bulletin 63(4):687-688. (1979, April)

The Johnny M mine is one of very few mines in the Ambrosia Lake district with uranium ore in two members of the Jurassic Morrison Formation; these members are the Westwater Canyon sandstone and the Brushy Basin shale. The Westwater Canyon ore is contained in the two upper sandstone units of the member, and the Brushy Basin ore is contained in the Poison Canyon sandstone. The sedimentary features and structures in the Westwater Canyon sandstone indicate that the sediments were deposited by a system of aggrading braided streams, possibly at the distal end of coalescing alluvial fans. The Poison Canyon sandstone was probably the result of deposition in a complex environment of meandering and braided streams. Paleocurrent direction indicators, such as fossilized-log orientation, foreset azimuths, and the axis of cross-beds and channel scours, suggest that the local paleostream flow was to the east and southeast. The uranium mineralization is closely associated with (1) local accumulations of carbonaceous (humate) matter derived from the decay of organic material, such as trees and plants; and (2) paleostream channels preserved in the rocks. The ore elements were derived from the leaching of volcanic air-fall tuffs and ash, which were introduced into the fluvial system during volcanic activity in the western United States. The mobile ore element ions were reduced and concentrated by humic acids and bacteria present in the fluvial system, and ultimately remobilized in the system into the forms present today. The uranium is thus envisioned as forming either essentially on the surface as the sediments were being deposited or at very shallow (20 ft; 6 m) depth.

<382>
Foster, J.P., and R.J. Quintanar, United Nuclear Corporation, Grants, NM

Anomalous Orebody Within Ambrosia Lake Trend at Sandstone Mine. AAPG Bulletin 63(4):688. (1979, April)

At the Sandstone mine, there is an anomalous orebody that lacks the characteristic coloring and gamma counts associated with known uranium ore at Ambrosia Lake. The orebody occurs along the downdip edge of a tongue of hematitic sand in the basal sand unit of the Westwater Canyon Member. The orebody is white to light gray, most likely because of a lack of indigenous humic material. The abundance of pyrite indicates the uranium is in the tetravalent state, probably coffinite. Preliminary analysis also indicates the presence of uranophane evidently altered from the coffinite. Equivalent U3O8 by gamma determination is usually 30 to 60 percent of actual U3O8, indicating that this orebody is relatively recent. Oxidizing meteoric water, forming a geochemical cell, remobilized the uranium minerals in the preexisting trend orebodies and deposited them downdip from the farthest extent of this cell. Post-Dakota deformation influenced the course of the migrating meteoric water and the extent of the redox interface controlling the orebody. As lower grades of U3O8 become economical, the potential for unknown reserves adjacent to the redox interface should not be overlooked. Areas of low-grade ore should be sampled to become aware of any equilibrium imbalances. An established sampling program coupled with more sophisticated beta-gamma instrumentation should remedy the inaccuracy of present-day gamma evaluations. (Auth)

<383>
Galloway, W.E., Bureau of Economic Geology, Austin, TX

Oakville Formation of Texas Coastal Plain - Depositional Systems, Composition, Structure, Geohydrology, and Uranium Mineralization. AAPG Bulletin 63(3):455. (1979, March)

The Oakville Formation consists of deposits of a bedload fluvial system composed of at least four major and several minor rivers that flowed across the Miocene Texas coastal plain. Rivers of the southwestern part of the system transported polymictic sand and gravel containing abundant volcanic clasts; stream deposits of the northeastern area are uniquely rich in reworked carbonate-rock fragments. Structures suggest highly variable to ephemeral flow and extensive development of crevasse splays. Bounding flood-plain muds consist of kaolinitic calcium to sodium montmorillonite. Illite is present locally. Hydrogeology and uranium mineralization are strongly influenced by a broad belt of subjacent Wilcox (Eocene age) growth faults. Mineralization and alteration patterns reflect the complex flow of groundwater within a stratigraphically and structurally compartmentalized aquifer. With evolution of the Oakville aquifer system, faults have acted both as flow boundaries and as loci for intrusion of deep-seated highly reducing brines and shallow meteoric groundwater, further obscuring primary ore-forming processes. Volcanic glass within and possibly above the Oakville provides a probable source for the uranium.

<384>
Gillerman, E., University of Kansas, Lawrence, KS

Uranium Mineralization in the Burro Mountains, New Mexico. Economic Geology 63:239-246. (1968)

Uranium minerals have been found in the Burro Mountains in the White Signal and Bullard Peak districts. In the White Signal district and adjacent areas, secondary uranium phosphate minerals are the principal uranium-bearing minerals. Autunite, torbernite, meta-torbernite, and an iron-uranium phosphate (probably bassetite) have been identified, with torbernite and meta-torbernite being the most abundant uranium-bearing minerals. The distribution of the uranium phosphates within the deposits appears to correlate with depth. Autunite is common in surficial exposure, but has not been found below 30 feet. Torbernite is present throughout the depth range explore in the workings, but not found below 180 feet in a drill hole that explored the Merry Widow vein. The uranium-iron phosphate is known only from below 100 feet in the Merry Widow Mine. Uraninite was identified at the Blue Jay deposit 2 feet below a small trench. Minerals associted with the uranium phosphates are mostly hydrous iron oxides, copper carbonates and native gold. The uranium deposits are localized in the vicinity of the intersections of diabase dikes and gold-bearing quartz-pyrite veins, probably due to the high phosphatic content of the diabase dikes and their susceptibility to alteration and release of phosphorus which fixed the uranium. In the Bullard Peak district, uranium occurs with nickel and cobalt arsenides and sulfarsenides in what are predominantly native silver veins. Within the veins, silver occupies the central portions, and the nickel and cobalt minerals, principally nickel skutterudite, are concentrated toward the margins. Uraninite occurs in the outermost zones of the veins with the nickel and cobalt minerals, never occurring with the silver. The veins are believed to be genetically associated with a nearby Late Cretaceous or Early Tertiary monzonitic intrusion. The uraninite is believed to have been emplaced during the last phases of silver and base-metal mineralization, or it may represent a second stage of metallization allied to fluorspar and gold mineralization of nearby areas. (JJT)

<385>
Green, M.W., USGS, Golden, CO

Disconformities in Grants Mineral Belt and Their Relation to Uranium Occurrence. AAPG Bulletin 63(4):689. (1979, April)

At least two major, regionally extensive, intraformational disconformities and numerous local ones are present in sedimentary rocks of Triassic, Jurassic, and Cretaceous ages in the Grants mineral belt. These disconformities, some of which have been known for many years, have proven useful in stratigraphic correlation and in differentiating genetically related rock sequences in the mineral belt. In addition, two of these disconformities, one local and the other regional, are significantly associated with the distribution of sandstone-type uranium deposits in the Jurassic Morrison Formation and the overlying Cretaceous Dakota Sandstone. The Westwater Canyon Member and laterally equivalent beds of the Recapture and Brushy Basin Members of the Morrison Formation are separated from underlying Jurassic rocks by an intraformational disconformity which marks a major change in depositional environment from predominantly sabkha-eolian dune to fluvial-lacustrine within the Jurassic sequence. This disconformity is economically significant in that all of the large uranium deposits in rocks of Jurassic age in the mineral belt occur within fluvial sandstone facies of the Morrison above the disconformity. Recognition of this disconformity in outcrop and in the subsurface is important in delineation of exploration target areas and resource assessment in the San Juan basin. Uranium deposits in the basal part of the Dakota Sandstone are associated with the well-known regional, southward-beveling disconformity present at the lower boundary of the Dakota throughout the San Juan basin and adjacent region. In the western part of the mineral belt, impermeable Brushy Basin shales have been truncated at this disconformity and uranium-bearing groundwaters from the Morrison Formation have migrated into basal organic-rich sandstone of the Dakota to produce several small to medium-sized uranium deposits.

<386>
Gulbrandsen, R.A., USGS, Washington, DC

Petrology of the Meade Peak Phosphatic Shale Member of the Phosphoria Formation at Coal Canyon, Wyoming. USGS Bulletin 1111-C, (pp. 71-146). (1960)

The Meade Peak Phosphatic Shale Member of the Phosphoria Formation is 143 feet thick at Coal Canyon and consists of dark thin-bedded phosphorites and carbonate and quartz-silicate rocks. The average chemical composition, in percent, of the member is: SiO2, 26.5; TiO2, 0.2; Al2O3, 4.5; Fe2O3, 1.8; MgO, 4.5; Na2O, 0.9; CaO, 27.0; K2O, 1.6; P2O5, 10.6; CO2, 3.8; F, 1.1; SO3, 2.0; H2O, 0.9; and carbonaceous material, 4.8. The "average" rock contains unusually high amounts of phosphorous and fluorine. The average Ca-Mg ratio for the member is 6, but it ranges from 88 for the average phosphorite to 2.9 for the average carbonate rock. Important minor constituents that occur in the rocks in significant amounts are vanadium, selenium, and uranium. The uranium content of the whole member ranges from 0.0005 to 0.034 percent and averages 0.004. The higher uranium contents are in phosphorites. Dolomite makes up 21 percent of the member and calcite, 8 percent. Carbonate-fluorapatite makes up 28 percent, and the quartz-silicate group of minerals makes up 33 percent of the member. The three principal compositional rock types are characterized by the dominance of a mineral or mineral group: carbonate-fluorapatite in phosphorite, calcite and dolomite in carbonate rock, and the quartz-silicate group of minerals in the quartz-silicate rocks. Most of the rocks are composed of silt-size particles, but many phosphorites are composed of pellets and oolites of sand size. The rock strata most commonly consists of beds 0.5 to 2 feet in thickness and occurs in unsystematic alteration of one upon another. There is no favored pair of rock types or sequence of the three types. Carbonate-fluorapatite, dolomite, and calcite, chemically related compounds that have calcium and carbonate ions in common, occur in the rocks of the member in three principal associations. These occurrences are considered to represent approximately the solid phase or phases of these minerals in equilibrium with sea water from which they formed. Where found alone, carbonate-fluorapatite represents a first-stage differentiation of sea water by evaporation, or a precipitation owing to sustained addition of phosphate to sea water by the dissolution of dead organisms, for example. The dolomite-carbonate-fluorapatite mixtures represent a second-stage differentiation following the precipitation of apatite alone, in which the two minerals form together in proportions high in dolomite. These two closely related kinds of mineral associations are dominant in the Coal Canyon section. The dolomite-calcite mixtures cover a wide range of proportions that is not readily explained in terms of simple phase relations. Under conditions in which dolomite is the single solid phase in equilibrium with sea water, however, calcite could precipitate metastably and change with time, while in contact with sea water, to dolomite. In this manner, the amount of dolomite formed is a function of the time during which calcite is in free contact with sea water, and all proportions of dolomite and calcite are possible. (Auth) (JRT)

<387>
Heinrich, E.W., The University of Michigan, Department of Mineralogy, Ann Arbor, MI

Some Rare-Earth Mineral Deposits in Mohave County, Arizona. Arizona Bureau of Mines Bulletin 167; 22 pp. (1960)

Pegmatites in the Aquarius Range, Mohave County, Arizona contain a variety of radioactive rare-earth minerals. Authenticated species are: monazite, xenotime, euxenite, yttrotantalite, gadolinite, and allanite. Fergusonite may also be present. The occurrence of yttrotantalite, several tons of which have been produced, is the first that has been established for the United States. Within one pegmatite, the sequence of rare-earth minerals is accompanied by an increase in yttrium rare earths and tantalum in younger minerals at the expense of Ce rare earths and Nb in older species. In each of the pegmatites, the two subgroups of rare earths do not form minerals of the same chemical class. The identity of the abundant rare-earth mineral in the Kingman Feldspar pegmatite is established as allanite. A sample of the allanite was found to contain 2.7 percent thorium and 0.14 percent uranium. (JRT)

GEOLOGY OF DEPOSITS

<388>
Jenkins, J.T., Jr., and S.P. Cunningham, Gulf Research and Development Company, Houston, TX

Depositional Environment of Poison Canyon Sandstone in Gulf Mariano Lake Mine. AAPG Bulletin 63(4):690. (1979, April)

A study of the depositional environment of the Poison Canyon Sandstone (Brushy Basin Member of the Upper Jurassic Morrison Formation) in the Mariano mine was undertaken to determine the relation of uranium occurrence to the depositional environment. An analysis of the sedimentary structures, paleocurrent measurements, isopach data, and electric-log shapes has led to the interpretation that the Poison Canyon Sandstone in the Mariano Lake mine vicinity is a sequence of bed-load deposits of a fluvial system. Paleocurrent measurements taken in the mine and at three outcrops of the Poison Canyon confirm findings from earlier work that indicated eastward current flow. The dominance of tabular cross-beds, channel scours, and trough cross-beds, the geometry of the Poison Canyon sandstones, and the chaotic sedimentary structures corroborate deposition in a braided-stream environment. The Poison Canyon sandstones may be subdivided into two lithofacies. A cross-bedded unit is characterized by large-scale tabular cross-beds, scour surfaces, medium to coarse grain size, poor sorting, angular to subangular grains, an abundance of feldspar grains, and clay rip-up clasts. A second unit is dominated by laminar bedding, fine grain size, moderate sorting, subrounded grains, and an abundance of quartz. The source area for the sands had been dominated by plutonic rocks. These facies cannot be separated on the basis of electric-log shape. Uranium ore occurs in both facies but is more abundant in the cross-bedded unit. The complexities of the braided-stream system greatly complicate any study of the interrelation of the uranium and the depostional environment. Obvious conclusions are that the grain size does not greatly influence the emplacement of the uranium, that the orebody at the Mariano mine is epigenetic, and that the sheetlike nature of the Poison Canyon sandstones suggests that the limiting factors on the ore boundaries are geochemical rather than stratigraphic. (Auth)

<389>
Johnson, C., Michigan Technological University, Department of Geology and Geological Engineering, Houghton, MI

The Uranium and Thorium Occurrences in Michigan's Precambrian Rocks. GJBX-48(76); Uranium and Thorium Occurrences in Precambrian Rocks, Upper Peninsula of Michigan and Northern Wisconsin, With Thoughts on Other Possible Settings, J. Kalliokoski, (pp. 87-135), 294 pp. (1976, June)

Thirty-eight radioactive occurrences of Northern Michigan are discussed in this section. Most of these showings are small and the radioactivity localized. The occurrences are classified into three categories: syngenetic, primary, and supergene. Syngenetic mineralization is restricted to sedimentary processes in which the formation of the host rock and the concentration of the ore minerals took place simultaneously and by the same mechanism. The only syngenetic occurrence noted is in the Goodrich Conglomerate and its consists of detrital grains of monazite. Primary mineralization is used to denote radioactive accessory minerals within granites and gneisses, which formed at the time the magma cooled. This type of mineralization accounts for the observed radioactivity at three places in northern Michigan; including a syenite dike, a migmatite, and a pegmatite. The rest of the radioactive occurrences (and the majority of them) are interpreted to be of supergene origin. They were formed by downward precolating ground waters which leached uranium from the surrounding rocks and reprecipitated it in traps and zones of reduction. The majority of these radioactive occurrences are caused by pitchblende and/or secondary uranium minerals, such as metatorbernite or meta-autunite, in Middle Precambrian metasediments; diabase dikes of uncertain age, and Keweenawan felsites. (JHT)

<390>
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Characteristics of Relevant Types of Precambrian Uranium Deposits. GJBX-48(76); Uranium and Thorium Occurrences in Precambrian Rocks, Upper Peninsula of Michigan and Northern Wisconsin, With Thoughts on Other Possible Settings, J. Kalliokoski, (pp. 15-37), 294 pp. (1976, June)

The six important types of Precambrian uranium deposits throughout the world are discussed in this chapter and the comparable Michigan deposits of each type are listed. The types of uranium deposits are as follows: (1) Uraniferous Precambrian Quartz Pebble Conglomerates, (2) Uranium in Granites and Pegmatites, (3) Uranium in Syenites and Nepheline Syenites, (4) Vein Deposits of Possible Supergene Origin in Precambrian Gneisses, (5) Vein Deposites of Possible Supergene Origin in Precambrian Metasedimentary and Volcanic Rocks, and (6) Uranium Associated with Diabase Dikes. Examples of each type of deposit discussed are: (1) Elliot Lake, Ontario, Witwatersrand, South Africa, and Jacobina, Brazil; (2) Rossing, Southwest Africa, Massif Central, France, and Spokane, Washington; (3) Ilimaussaq, Greenland; (4) Beaverlodge and Rabbit Lake areas, Saskatchewan; (5) Rum Jungle-Alligator River Province, Northern Territories, Australia; and (6) Theano Point area, Ontario. (JHT)

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The Precambrian Geology of Michigan.
GJBX-48(76); Uranium and Thorium Occurrences in
Precambrian Rocks, Upper Peninsula of Michigan
and Northern Wisconsin, With Thoughts on Other
Possible Settings, J. Kalliokoski, (pp. 30-86),
294 pp. (1976, June)

The Lower Precambrian rocks throughout most of the western Upper Peninsula are represented by granites, gneisses, basic and felsic volcanic rocks, amphibolites and metasediments. The granites and gneisses are exposed in relatively large areas of northern Michigan, and, from evidence of provenance in conglomerates, they have been exposed sporadically both prior to and after the Penokean orogeny, 1900 m.y. ago. Because of this, their possible role in the formation of supergene uranium prospects cannot be overlooked. The Lower Precambrian sedimentary rocks in northern Michigan consist of the Dickinson Group. The Group includes the East Branch Arkose, Solberg Schist, and Six Mile Lake Amphibolite; all have been metamorphosed. Minor radioactivity has been noted in outcrops of the East Branch Arkose in Sec. 8, T42N, R29W. The Middle Precambrian metasedimentary and metavolcanic rocks are separated from the basement rocks by a major unconformity, and have been referred to the Marquette Range Supergroup. They have been divided into four groups and their lithologic variations record episodic verticle movement of basement of basement granites during sedimentation. The Goodrich Quartzite of the Baraga Group contains a coarse basal conglomerate which occurs in lenses 220-300 feet thick, but thins rapidly along strike. In places the Goodrich Quartzite also contains detrital grains of monazite along the bedding planes, where the monazite settled out as a heavy black sand. The formation contains only trace amounts of uranium, but it is possible it may contain detrital uraninite, as in the Blind River type deposits. The Paint River Group is the youngest of the Middle Precambrian metasediments. Nine radioactive occurrences are found in the Riverton Iron Formation, a member of the Paint River Group. All of the occurrences are at or near stratigraphic contacts between oxidized iron formation and black slate. Keweenawan rocks in Michigan are separated from the older rocks by a major unconformity formed subsequent to the Penokean Orogeny. The series consists of a thick sequence of mafic flows and continental sedimentary rocks. (JMT)

<392>
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Moscow, ID

Geology of the Uranium Deposits near Stanley,
Custer County, Idaho. Idaho Bureau of Mines and
Geology Pamphlet No. 117; 40 pp. (1959, June)

The Stanley uranium area is in T11N, Rs 13 and 14 E, Boise Principal Meridian, approximately midway between the Idaho towns of Challis and Ketchum on U.S. Highway 93. The Cretaceous Idaho Batholith, dominantly quartz monzonite, forms the basement of the area and it is nonconformably overlain by the Oligocene-Miocene Challis Formation. The Challis Formation in the Stanley area consists of 2,000 feet of tuffs and flows of intermediate composition with a 100 foot sequence of clastic terrestrial sedimentary rocks at the base. Silicic hypabyssal rocks, probably of early Tertiary age, intrude the batholith. Fractures are the dominant structural feature, with the major fracture sets striking N45 degrees W, N 60-70 degrees E, and north. Uranium occurs in: (1) steeply dipping fractures in batholithic rocks and silic intrusive rocks, and (2) disseminated in beds of arkosic conglomerate at the base of the Challis Formation. Uranium is the ore mineral in at least one of the bedded deposits. Both supergene ores and hypogene ores are present in the Stanley area. Few of the deposits have been explored to depths greater than 20 feet. The known deposits are distributed in a northwesterly trending belt across the Stanley area. Fractures are the primary control in all deposits, and the N 45 degree W set of fractures is most important. The control of the deposits by fractures, the presence of uraninite, marcasite, and stibnite in the ore, and the hydrothermal alteration of the host rocks indicate a hydrothermal origin for the deposits. Sixteen groups of claims have been staked in the area, totaling over 230 claims. Each group is described. Approximately 2,300 tons of ore averaging near 0.25 percent U_3O_8 have been produced from the Stanley uranium deposits. (Auth) (JST)

GEOLOGY OF DEPOSITS

<393>
Keys, W.S., and P.H. Dodd, AEC, Washington, DC

Lithofacies of Continental Sedimentary Rocks Related to Significant Uranium Deposits in the Western United States. Peaceful Uses of Atomic Energy, Vol. 2, Survey of Raw Material Resources, Proceedings of the 2nd International Conference, Geneva, Switzerland, September 1-13, 1958. United Nations, New York, (pp. 367-378), 843 pp. (1958)

Uranium deposits and districts in the United States suggests certain consistent relationships between features of the sedimentary host rocks and uranium ore. In the United States, most uranium deposits occur in continental sedimentary rocks ranging in age from Permian to late Tertiary. Approximately 95% of the ore reserves are in sedimentary rocks of the following ages: Triassic [23 X 10(E+3) tons of U_3O_8], Jurassic [148 X 10(E+3) tons of U_3O_8], and Tertiary [32 X 10(E+3) tons of U_3O_8]. Lithofacies of the host rocks can be used as local exploration guides. Lack of homogeneity of texture and composition of the ore-bearing sediments is often cited as an ore guide. Most of the host rocks are fine- to medium-grained sandstones. Sedimentary textures are important because of their direct relationship to the porosity and permeability of host rocks. Transmissivity studies of the ore-bearing rocks of the Colorado Plateau indicate that fluviatile rocks generally have lower regional transmissive capacity than the less favorable eolian and marine rocks, but are characterized by a wide range of local transmissivity. The host rock is usually underlain or overlain by relatively impermeable beds, either argillaceous or well-cemented arenaceous rocks. Many ore bodies are localized near these barriers, usually adjacent to the lowest barrier. These surrounding, less permeable beds have apparently served to channel the flow of the ore-bearing solutions. As a rule, the most permeable sandstones in a district are not ore bearing but probably served as conduits through which the uraniferous solutions moved. Many large ore deposits are localized just above stratigraphic discontinuities, especially where those breaks are marked by a relatively impermeable bed. Paleostream channels of varying dimensions are probably an important ore control for most of the ore bodies of the United States. Channels or similar features, variously called braided channels, straths, swales, scours, depositional basins, or elongate lenses, have been suggested as ore controls in all of the major districts in the western United States. The depositional environment of the favorable host rocks is a zone of change from fast-water channel environment to the slow- or stagnant-water environments of flood plains and abandoned channels. (JHT)

<394>
Langford, F.F., University of Saskatchewan, Department of Geological Sciences, Saskatoon, Saskatchewan, Canada

Uranium Deposits in Australia. Uranium Deposits, Their Mineralogy and Origin, Short Course Handbook, Volume 3, M.M. Kimberley (Ed.). University of Toronto Press, Toronto, Canada, Ch. 7, (pp. 205-216), 521 pp. (1978, October)

Uranium was first produced in Australia in 1906 from Radium Hill. In 1944, intensive exploration began resulting in the development of the Rum Jungle, South Alligator River Valley, Radium Hill, and Mary Kathleen deposits. After 1965, due to increased uranium prices, a resurgence of uranium exploration activity resulted in the discovery of the major deposits at Lake Frome, the Ngalia basin, and Yeelirrie. By far the largest uranium deposits in Australia are located in the Darwin area in the northern part of the Northern Territory. Major vein-type deposits of Nabarlek, Jabiluka, Ranger, and Koongarra occur in the part of this area known as the Alligator Rivers Region. South of these deposits, the South Alligator River valley contains a large number of showings and a number of small mines. On the west side of the area, the Rum Jungle camp has four economic uranium deposits and some base metal mines. It is believed that the uranium resources of the Darwin area exceeds 350,000 tons of U_3O_8; considerably more than the other uranium deposits in Australia combined. Ore deposits from all three camps in the Darwin area are close to, if not in contact with, the unconformity between the Lower and Middle Proterozoic. The mineralogical, structural, and stratigraphic situations of these deposits are very much like those of the Athabasca deposit in Saskatchewan. Several other deposits outside the Darwin area are of economic importance. These include the Westmoreland deposit, Mary Kathleen mine, Ngalia Basin deposit, Lake Frome area, Yeelirrie and Maureen deposits. (JHT)

<395>
Lindsey, D.A., USGS, Denver, CO

Geology of Volcanic Rocks and Mineral Deposits in the Southern Thomas Range, Utah: A Brief Summary. Brigham Young University Geology Studies 25(1):25-31. (1978)

Uranium deposits have been discovered in the Thomas Range. These deposits occur as (1) fluorspar pipes, (2) in beryllium deposits in tuff, (3) in tuffaceous conglomerate and sandstone at the Yellow Chief mine, and (4) veinlets of opaline silica at many localities. The only production of uranium has been from the Yellow Chief deposit, which was mined between 1959 and 1962. The ore at the Yellow Chief is beta-uranophane [$Ca(UO_2)_2(SiO_3)_2 . 5H_2O$]. It occurs in lenses as much as 6 meters thick and 90 meters long that are approximately concordant to the bedding. The mineral weeksite [$K(UO_2)_2(Si_2O_5)_3 . 4H_2O$] occurs in the limestone conglomerate that overlies the tuffaceous sandstone at the Yellow Chief Mine. Both minerals occupy interstices and fractures and coat sand grains and clasts in the conglomerte. Uranium also occurs in the structure of opaline silica veinlets in tuff at many places in the Thomas Range, with the most uraniferous opal veinlets in the rhyolitic ash-flow tuff of the oldest volcanic group at the Autunite No. 8 prospect on the east side of Topaz Mountain. None of these occurrences have produced ore. Important deposits of fluorspar and beryllium have also been found in the Thomas Range. (JHT)

GEOLOGY OF DEPOSITS

<396>
Lindsey, D.A., H. Ganow, and W. Mountjoy, USGS, Denver, CO

Hydrothermal Alteration Associated with Beryllium Deposits at Spor Mountain, Utah. USGS Professional Paper 818-A; 20 pp. (1973)

The beryllium deposits at Spor Mountain occur in waterlaid tuff that contains carbonate clasts. Vitric and zeolitic tuffs are present outside the mineralized area where argillic and feldspathic tuffs are present within the mineralized area. Early alteration of the tuff was characterized by argillization and addition of Si, Al, Fe, H2O, F, Be, Li, and many trace elements. The beryllium ore body and associated fluorite are near the top of the tuff and are underlain by a thick zone containing lithium-bearing trioctahedral montmorillonoid clay and associated calcite. Beryllium (as bertrandite), lithium, uranium, and other elements are concentrated in the fluorite-rich nodules, and magnesium, lithium, and zinc are concentrated in tricotachedral monmorillonoid clay nodules. (JHT)

<397>
Livingston, S.A., Bokum Resources Corporation, Santa Fe, NM

Geology and Development of Marquez, New Mexico Uranium Deposit. AAPG Bulletin 63([illegible]):691. (1979, April)

Uranium deposition in the Marquez, New Mexico, area occurs almost exclusively in the lower Westwater Canyon Member of the Morrison Formation of Jurassic age. The average aggregate thickness of the Westwater is 90 m but ranges from a minimum of 73 m to a maximum of 100 m. A "K" shale separates the upper and lower Westwater sandstone boundaries. The lower Westwater sandstone development is more pronounced in an east-southesat direction parallel with strike of the orebody(ies). Three distinct ore zones were deposited in peneconcordant elongate patterns. The upper zone occupies a stratigraphic interval just below the "K" shale and two lower zones lie above and below the "K1" shale. Coffinite and uraninite predominate as the stable uranium species; other extrinsic elements were added during the mineralization process. Humates undoubtedly exerted major control on formation of the uranium. Ferrous iron pervades both within and outside the deposit whereas ferric iron, through limited in quantity, is confined principally to the orebody(ies). The lower "K1" shale, parameters of permeability, and recurrence of meanders along the paleochannels also seem to influence enrichment. Surface drilling is continuing, a vertical mine shaft to approximately 2,100 ft (630 m) is nearing completion, and a mill is being constructed on the property. (Auth)

<398>
Lupe, R., USGS, Denver, CO

Depositional Environments as a Guide to Uranium Mineralization in the Chinle Formation, San Rafael Swell, Utah. Journal of Research of the USGS 5(3):365-372. (1977, May)

Uranium deposits in the San Rafael Swell are related to sedimentary depositional environments in the Upper Triassic Chinle formation. The sedimentary textures resulting from depositional processes operating in low-energy environments appear to have influenced uranium mineralization. The Chinle consists of three thining-upward, fluvial-lacustrine sequences. Uranium minerals are concentrated in the lower part of the lowest sequence in areas where sediments of low-energy environments are complexly interbedded with sediments of other environments. Areas favorable for uranium exploration exist in the subsurface to the north, west, and south of the Chinle outcrop in the Swell. This determination is based on the spatial distribution of depositional environments and the pattern of Chinle deposition through time. (Auth)

<399>
Miller, D.N., Jr., Wyoming Geological Survey, Laramie, WY

Wyoming's Resources - Green River Basin. Geology and Mineral Resources of the Greater Green River Basin, Proceedings of the Twenty-Fifth Field Conference, Casper, WY, September 17-19, 1973. Wyoming Geological Association, Casper, (pp. 23-26), 246 pp. (1973)

The mineral resources of the Green River Basin of Wyoming are discussed very generally in this paper. The only uranium mining underway in the basin at the time the paper was written is in the vicinity of Crooks Gap in the northeast margin of the Great Divide Basin. Indications are that there will be more exploration in the future. Occurrences of uranium bearing rocks such as uraninite, schroeckingerite in association with coals, and uranium phosphate have been reported by mining companies, the USGS, and by the AEC. The most significant deposits have been encountered in Eocene strata in an area south of Crooks Gap. Commercial grade ore is anticipated in any of the numerous Paleocene sandstones and in the arkosic sandstones of the Eocene Battle Spring Formation. (JHT)

<400>
Newton, J., D. LeMoine, C.W. Adams, A.L. Anderson, and J.A. Shively, Idaho Bureau of Mines and Geology, Moscow, ID

Study of Two Idaho Thorite Deposits. Idaho Bureau of Mines and Geology Pamphlet No. 122; 53 pp. (1960, September)

The thorium deposits of the Hall Mountain area in Boundary County and the thorium deposits of the Lemhi Pass area, Idaho are discussed. Thorite lode deposits occur in the Hall Mountain area. All thorite prospects in this area were located along faults and calcite was a preferential host for thorite. The thorium deposits in the Lemhi Pass area are contained in broadly folded and faulted metamorphosed sedimentary rocks belonging to the Precambrian Belt series. These rocks are intruded by scattered small dioritic and lamprophyric dikes of uncertain, but probably Late Cretaceous or Early Tertiary age. The deposits are characteristically blackened fracture zones and veins containing thorium. Because of their mineral associations and structural relations, the deposits are classed as hydrothermal veins. (JHT)

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GEOLOGY OF DEPOSITS

<401>
Nininger, R.D., AEC, Washington, DC

Geologic Distribution of Nuclear Raw Materials. Peaceful Uses of Atomic Energy, Vol. 2, Survey of Raw Material Resources, Proceedings of the 2nd International Conference, Geneva, Switzerland, September 1-13, 1958. United Nations, New York, (pp. 1-10), 843 pp. (1958)

Of the many metals for the industrial utilization of atomic energy, the ores of four - uranium, thorium, beryllium, and zirconium - have special significance as nuclear raw materials. As the intensive and widespread uranium geologic and exploration program of the past decade has proceeded, changes have taken place in the relative importance of the various types of uranium deposits. A decade ago uranium deposits in sandstones and other sedimentary formations were considered, at best, a minor supplementary source; the great potential of the metaconglomerate or conglomerate deposits was not yet recognized and the significance of the oxidized outcrops of many vein-type uranium deposits was not understood. Uraniferous Precambrian conglomerates lithologically similar to those in Canada and South Africa are known in many parts of the world. Experience since the Blind River discovery, however, indicates that conglomerate deposits from which uranium can be produced at present prices are the exception. Because of the widespread occurrence of deposits in sedimentary rocks and the large areas of favorable sedimentary terrane yet to be explored, this type of deposit will probably continue to increase in relative importance. Reserves of such deposits represent more than 95 percent of the recorded reserves in the United States which total about 220,000 tons of U3O8 (1958). The remaining reserves are in vein and vein-type deposits. Important production of sandstone ores now comes from the stratigraphic units each in rocks of Triassic, Jurassic, Cretaceous, and Tertiary age. The rapid discovery and development of deposits in sedimentary rocks give promise of the continuing discovery of large reserves of this type in the United States as well as in areas of similar lithology and structure elsewhere in the world. Vein-type uranium deposits will probably remain in third place in importance. In vein-type deposits, uranium is often the sole extractable metal and is seldom in association with more than one co-product. Economic deposits of uranium are now known in veins in granites of Hercynian and Tertiary age; in fracture zones at the contact of granite and metamorphosed sedimentary rocks; in pyrometasomatic deposits; in pipelike deposits in metasedimentary rocks unrelated to intrusives; in pegmatitic zones in gneiss; and in fault-controlled deposits in Tertiary volcanic rocks. Although continued exploration may well discover reserves of low-cost uranium sufficient to last into the next century, the world may eventually turn to the almost unlimited reserves of low-grade uranium bearing shale, phosphorite, and granite. Current annual United States production of uranium as a by-product of the phosphate industry is about 100 tons. No production of uranium from shale, phosphorite, or granite is presently feasible. (JMT)

<402>
Olson, J.C., and S.R. Wallace, USGS, Denver, CO

Thorium and Rare-Earth Minerals in Powderhorn District, Gunnison County, Colorado. USGS Bulletin 1027-O; 32 pp. (1956)

Thorium was discovered in the Powderhorn District of Gunnison County, Colorado in 1949. Since that time over 33 deposits have been found in an area 6 miles (9.7 km) and 20 miles (32.2 km). The district is underlain primarily by pre-Jurassic metamorphic and igneous rocks, most of which are of Precambrian age. These rocks are overlain by sandstone of the Morrison Formation and by volcanic rocks of the Alboroto Group and the Hinsdale Formation. The thorium deposits occur in or near alkalic igneous, the greatest mass of which is the Iron Hill composite stock which occupies an area of 12 square miles (31.2 square kilometer). The thorium deposits are veins and mineralized shear zones that range from a few inches to 18 feet in width and from a few feet to 3,500 feet in length. The veins are composed of calcite, dolomite, siderite, anderite, quartz, barite, pyrite, sphalerite, galena, goethite, apatite, alkali feldspar, and a number of other minerals. At least part of the thorium occurs as thorite or thorogummite. A small amount of what has tentatively been identified as xenotime is found in one deposit and several minerals containing rare earth metals of the cerium group are found in the carbonate veins near Iron Hill. The radioactivity of the deposits appears to be due almost entirely to thorium and its daughter products. The thorium oxide content of a selected high-grade sample from the Little Johnnie vein is as much a 4 percent, but most veins contain less than 1 percent. The Little Johnnie vien, which was mapped in detail, was found to be a mineralized fault zone that ranges less than 6 inches to 5 feet in width and can be traced discontinuously for a distance of more than 3,500 feet. The thorium-bearing material occurs as irregular veinlets and thin films introduced along the fault zone. Near its west end the vein is broken by many faults in a zone that marks the edge of a roughly circular fault block. (JMT)

<403>
Osterwald, F.W., USGS, Washington, DC

Structural Control of Uranium-Bearing Vein Deposits and Districts in the Conterminous United States. USGS Professional Paper 455-G, (pp. 121-146). (1965)

Uranium-bearing veins in the United States are principally fissure-filling deposits in faults, joints, or fracture zones that have resulted from compressive, tensile, or torsional stresses. The individual ore bodies within vein deposits are tabular, sheetlike masses or ore shoots along veins, irregular stockworks along fault zones, or pipelike masses either in fault intersections or in blocks of broken ground. Many veins consist of gouge or breccia containing uranium minerals. Rocks adjacent to faults, joints, or fault zones may also contain uranium if they are porous or reactive, or if they are broken. Most uranium-bearing vein districts in the United States are in structural environments in which subsidiary intermediate to small-scale faults and folds are related spatially to large- to intermediate-scale folds, anticlinal uplifts, crystalline-rock masses, or faults. Deposition of uranium commonly occurs late in the structural history of a district. (Auth)

<404>
Pipiringos, G.N., W.A. Chisholm, and R.C. Kepferle, USGS, Washington, DC

Geology and Uranium Deposits in the Cave Hills Area, Harding County, South Dakota. USGS Professional Paper 476-A; 64 pp. (1965)

The geology and uranium deposits of the Cave Hills area, in north-central Harding County at the northwest corner of South Dakota, including 215 square miles of timbered buttes and ridges, are discussed. The rocks exposed in the Cave Hills are, in ascending order, the Hell Creek Formation of Late Cretaceous age, the Ludlow and Tongue River Members of the Fort Union Formation of Paleocene age, and the Chudron Formation of early Oligocene age. The rocks consist mostly of swamp and stream deposits but include brackish water or near-shore marine sediments. The total thickness reaches 800 feet. The Hell Creek Formation consists of clay shale, carbonaceous shale, siltstone and sandstone. Neither coal beds nor uranium deposits were noted in the formation. The Ludlow Member of the Fort Union Formation consists of gray clay shale, greenish-gray siltstone, and gray sandstone. Major coal beds and uranium deposits are located in this unit. The Lonesome Pete coal bed is one of the thickest and purest of all coal beds in the area. The Tongue River Member of the Fort Union Formation is crossbedded sandstone with interbeds of siltstone and claystone. Impure coal beds may be found in this unit, but are not of the same quality as those found in the Ludlow Member. One of the largest local uranium deposits is located in Coal Bed E, found in the Tongue River Member. The Chadron Formation is a conglomerate, very coarse grained sandstone. Tuffaceous sandstone and claystone, bentonite, tuffaceous bentonitic claystone are silicified limestone are common as well. The small quantities of uranium occurring in the Fort Union Formation are not of ore grade, but these concentrations do exist in the E and F Coal Beds of the Tongue River Member. Coal Zone C, and the Lonesome Pete and Carbonate ore zones of the Ludlow Member are probably in the form of organouranium complexes. In this form uranium is not visible and must be detected with radiometric instruments or by chemical analyses. Relatively minor amounts of uranium occur as a film or scaly mass of yellowish uranium minerals. The most abundant uranium minerals occurring in this area are metatorbernite, followed by meta-autunite and metazeunerite. (HBW)

<405>
Ridgley, J.L., USGS, Denver, CO

Roll-Type Uranium Occurrence at Dennison-Bunn Claim and Possibility of Uranium Deposits in Eastern Part of San Juan Basin, New Mexico. AAPG Bulletin 63(4):692-693. (1979, April)

Uranium at the Dennison-Bunn claim, south of Cuba, New Mexico, along the east margin of the San Juan basin, occurs in stacked fluvial-channel sandstones interbedded with gray-green mudstones of the Westwater Canyon Sandstone Member of the Morrison Formation of Juassic age. Although all the sandstone units are mineralized, the greatest concentration of uranium occurs in the uppermost sandstone unit. The uranium deposits are low to medium grade, range from 0.001 to 0.07 percent U308, and are irregularly distributed along the margins of intertonguing oxidized and unoxidized sandstone. The configuration indicates that these are roll-type uranium deposits and that they formed at the interface between oxidizing and reducing solutions. The host rocks dip 45 degrees west into the basin. Reconstruction of the tectonic and sedimentologic history along the eastern margin of the basin suggests that conditions favorable for the solution, transportation, and deposition of uranium probably occurred from Late Cretaceous into Eocene time. Uranium in the mineralizing solutions may have originated from within the Morrison Formation or may have been leached from the Paleocene Ojo Alamo Sandstone or Nacimiento Formation, or from the Eocene San Jose Formation which once covered the area. Similar uranium deposits occur in the Morrison Formation at the Goodner lease, north of Cachana Spring. The presence of oxidized sandstone in the Morrison Formation along the outcrop belt from Cachana Spring north to Cuba suggests that additional uranium deposits may exist at the boundaries of oxidized and unoxidized sandstone in the subsurface along the eastern margin of the San Juan basin. (Auth)

<406>
Riese, W.C., and D.G. Brookins, Gulf Mineral Resources Company, Albuquerque, NM; University of New Mexico, Albuquerque, NM

Mount Taylor Uranium Deposit, San Mateo, New Mexico. AAPG Bulletin 63(4):693. (1979, April)

The Mount Taylor uranium deposit is located at the extreme eastern end of the Ambrosia Lake district in the Grants mineral belt of New Mexico. Ores are confined to the Westwater Canyon Member of the Jurassic Morrison Formation and are spatially related to meanders in the paleochannels which deposited the arkosic sands of this member. The shape of the deposit roughly resembles the roll fronts of the Wyoming Tertiary basins. This deposit resembles the deposits of the Wyoming basins chemically as well. Arsenic, selenium, molybdenum, and several other less commonly analyzed trace elements occur in zones across the orebody, parallel with the direction of dip and indicative of a redox cell. Mineralogically, however, the Mount Taylor deposit differs significantly from those in the Wyoming basins and, surprisingly, from most of the other deposits in the Ambrosia Lake district. It does not reside at an iron redox interface nor is it very pyritiferous. It does have concentrations of calcite along its downdip and bottom edges. Montmorillonite, chlorite, and kaolinite show a regular zonation from the unaltered downdip sediments, through the ore zone, and into the updip altered sediments. No primary uranium-bearing minerals have been identified. The deposit shows a complex relation to organic materials in the sediments indicating two periods of organic enrichment of the sediments. The nature of this relation implies that organic transport mechanisms may have been as important in ore genesis as inorganic mechanisms. (Auth)

<807>
Pistorcelli, S.J., Western Nuclear Inc.,
Albuquerque, NM

Geology of Eastern Smith Lake Ore Trend. AAPG Bulletin 63(4):693-694. (1979, April)

The ore trend explored by Western Nuclear, Inc. at Smith Lake, lies in approximately six sections in T15N, R13W of McKinley County, New Mexico. All of the orebodies lie within the Brushy Basin Member of the Jurassic Morrison Formation which contains essentially three distinct sandstone units at this location. For exploration purposes this breakdown is adequate, although the sandstones do become exceedingly complex on a small scale. The Smith Lake ore lies along the southern margin of the Chaco slope. The regional dip is quite uniform at about 2 degrees north-northeast. North of the deposits running subparallel to the east-west ore trend is the Mariano Lake anticline. At the west end, the anticline dies out at the Pinedale monocline and does not extend to the Bluewater fault zone on the east. The Bluewater fault is a normal, high-angle fault, downthrown to the east, and essentially forms the eastern boundary of the area. The orebodies are aligned approximately east-west and are generally arcuate. The geometry of the ore is controlled by the stream-channel systems in the Brushy Basin sandstones. Some of these orebodies coincide with the redox interfaces that have been found. Those that do can assume the geometry of a typical roll-front type of orebody. Three hypotheses for depositional controls are: (1) Laramide structures are spatially associated with the ore and have been considered by some geologists as a depositional control; (2) the change of lithologies from sandstones to mudstones down the hydraulic gradient also may have affected ore deposition; and (3) steam channel systems with carbonaceous material localizing the ore is a viable control as well. (Auth)

<808>
Roscoe, S.M., Canada Geological Survey, Ottawa, Ontario, Canada

Huronian Rocks and Uraniferous Conglomerates in the Canadian Shield. Geologic Survey of Canada Paper 68-40; 205 pp. (1969)

Uranium ore deposits of the Elliot Lake-Blind River area and other beds of radioactive, pyritic, quartz-pebble conglomerate near the north shore of Lake Huron, occur within greenish, very coarse grained, crossbedded, argillaceous, feldspathic quartzite in the Elliot Lake Group at the base of the Huronian Supergroup. Volcanics, formerly considered pre-Huronian, in the Espanola-Sudbury area east of Elliot Lake may be correlative with basalt that comprises much of the Elliot Lake Group to the west in the Thessalon-Sault Ste. Marie area. Overlying Huronian formations, Hough Lake, Quirke Lake and Cobalt Groups, in ascending order, each contain conglomeratic greywacke of probable glacial origin overlain by argillaceous strata (including limy beds in the Quirke Lake Group) in turn overlain by subarkose. Sedimentary strata totalling more than 30,000 feet in the southeastern part of the region thin sourceward to the north. Grain sizes in clastic rocks coarsen and lower strata wedge out northward beneath disconformably overlying strata. The dominantly continental, early Aphebian (2.1-2.5 x 10(E+9) years) Huronian rocks are probably older than most other Aphebian rocks in the Canadian Shield which are dominantly marine, deposited on relatively smooth surfaces under comparatively stable conditions. Probable Huronian correlatives in the Mistassini region, Quebec, contain radioactive conglomerates and limited areas of similar rocks occur near Padlei, Northwest Territories. Highly metamorphosed remnants of analogous strata may be present in the Grenville and Churchill Provinces. Deposition of Huronian uraniferous conglomerates was controlled by the disposition of Huronian lava fields and by tectonic movements during sedimentation as well as by local and sourceward topographic features. Exploration possibilities near Elliot lake, where ore is associated with valleys in basement greenstone, are mainly at depths greater than 3,000 feet. Conglomeratic zones may occur at depth off the northeast margin of the Thessalon Volcanics as they do off the northwest margin of the Stobie Volcanics in the structurally complex Agnew Lake area. Uraninite and many other heavy minerals, including pyrite in the oligomict conglomerates, are detrital but authigenic brannerite, pyrite and other minerals are also present. The highest grade ores represent headward and medial concentrations of the heaviest detrital grains within more extensive placers. The survival of abundant detrital pyrite and uraninite, a deficiency of ferric iron in continental Huronian rocks and in underlying ancient residual soils, and the apparent lack of conglomeratic deposits or the Huronian-Witwaters and type in post-Aphebian rocks, may indicate that the early Aphebian atmosphere was a reducing one. (Auth)

<809>
Scholl, W.U., Laboratory for Sediment Research, Heidelberg, Federal Republic of Germany

Der Sudwestliche Randbereich der Espinhaco-Zone Minas Gerais, Brasilien. Geologische Rundschau 61(1):201-216. (1972, March)

The paper is based on geological mapping in Precambrian metamorphic rocks at the SE border of the Sao Francisco Basin. The oldest units are the Preminas rocks, which are overlain by the miogeosynclinal, quartzitic facies of the Minas Series. These units are unconformably overlain by the younger Sao Francisco Series. The later is subdivided into a marginal facies with coarse-grained clastics, the Macaubas, and a fine clastic and calcareous basin facies, the Bambui. The Sao Francisco Series was involved in the final phase of the Minas orogeny. The quartzites of the Minas and Macaubas are intensively thrust-faulted now overlying the Bambui. In the Bambui only large amplitude folding developed. Based on the tectonical and the sedimentological relations it is assumed that the Sao Francisco Series is the molasse of the Minas geosyncline. (JMT)

Cited as a reference in McNeil, M., "Geology of Brazil's Uranium and Thorium Occurrences," under ERDA Contract E(05-1)-1664.

<010>
Sharp, B.J., and B.L. Hyerson, AEC, Division of Raw Materials, Salt Lake City, UT

Preliminary Report on Uranium Occurrence in the Atlanta Area, Lincoln County, Nevada. RME-2048; 18 pp. (1956, January)

Uranium was discovered on the Blue Bird claims in the Atlanta area, Lincoln County, Nevada, in 1954. This deposit is situated approximately 35 air miles north of Pioche, Nevada. The geology of the area consists of moderately folded and highly block-faulted sedimentary rocks of Ordovician age. These sediments are overlain by Tertiary volcanic rocks which have been disturbed by some of the faulting. Intrusive breccia pipes in the Ely Springs dolomite, the youngest of the Ordovician sedimentary rocks have been silicified and mineralized and apperently controlled the localization of the gold, silver, and uranium minerals. The Blue Bird workings are in a silicified breccia pipe which contains quartzite fragments and silicified fragments of limestone and dolomite. Uraninite has been identified by X-ray methods in the silicified matrix of the rock. Three diamond drill holes on the property provided geologic information. Anomalous radioactivity was detected at a number of similar silicified breccia zones, including the Atlanta mine and several abandoned gold and silver workings in the Atlanta region. Surface and airborne prospecting of the Ely Springs dolomite is recommended in this region, especially near silicified breccia pipes. (Auth)

<011>
Staatz, M.H., USGS, Denver, CO

Geology and Description of the Thorium-Bearing Veins, Lemhi Pass Quadrangle, Idaho and Montana. USGS Bulletin 1351; 94 pp. (1972)

The Lemhi Pass quadrangle lies astride the Continental Divide in the east-central part of the Beaverhead Mountains. The quadrangle, though only a part of the much larger Lemhi Pass thorium district, is the area of the most abundant thorium veins. Rocks of the Belt Supergroup underlie the entire quadrangle and are at the surface over about 60 percent of the area. Fine-grained micaceous quartzite is the dominant rock type. The Challis Volcanics, which at one time overlaid the Belt rocks, are now preserved in downfaulted blocks and as erosional remnants. Diorite Dikes are scattered through the rocks of the Belt Supergroup; these dikes were emplaced in Tertiary time after the Challis Volcanics. The rocks of the area are deformed by several sets of faults and a few folds. Three principal types of veins occur at the 107 mapped localities in the Lemhi Pass quadrangle. They are as follows: (1) veins that contain thorium, (2) veins that contain copper but do not contain thorium, and (3) barren quartz veins. The thorium veins are, by far the most common. The range in thickness from paper thin to 30 feet, and in length from a few feet to at least 3,900 feet. The viens occur along small faults and shears and most of them are near the Lemhi Pass, Bull Moose, or Dan Patch faults. The veins are sheared and brecciated, and earlier gangue minerals are veined by later minerals. The thorium-bearing veins consist principally of quartz or quartz and microline gangue. The gangue minerals are cut by veinlets of goethite and hematite that contain thorite and less commonly, monazite. Thirty-nine minerals have been identified from various veins, but only seven minerals - quartz, magnetite, specularite, goethite, thorite, microcline, and rutile - occur in at least two-thirds of the veins. Other moderately common minerals are barite, pyrite, black manganese oxide minerals, red earthy hematite, monazite, muscovite, and apatite. In addition to thorite and monazite, the thorium-bearing minerals brockite and allanite have been identified in several veins. Some of the thorium occurs in limonite. The average thoria content of some of the better explored veins commonly exceeds 0.25 percent. The overall rare earth content is about equal to the thoria content. Copper bearing veins are not as common as thorium-bearing veins and they consists principally of primary and secondary copper minerals in a quartz gangue. Barren quartz veins are shorter than veins of the other two types. The veins of the Lemhi Pass quadrangle are probably Tertiary in age, forming after the Challis Volcanics and the diorite dikes. The copper-bearing veins are older than the thorium-bearing veins, but the relative age of the barren quartz veins to the other vein types is not known. (JMT)

<012>
Staatz, M.H., USGS, Denver, CO

I and L Uranium and Thorium Vein System, Bokan Mountain, Southeastern Alaska. Economic Geology 73(4):512-523. (1978, June)

The I and L vein system is a group of veins near the southeast part of the Bokan Mountain stock. The veins are unique in that they contain significant amounts of uranium, thorium, and rare earths - an unusual combination - and because of the distribution of their rare earths. The host rocks of the vein system are predominantly plutonic, although some metamorphic rocks are present. Typically the veins are thin, rarely exceeding 5 feet in thickness, and they are characterized by abrupt changes in thickness. They transect parts of the Upper Triassic-Lower Jurassic Bokan Mountain granite throughout their northwestern extent and Ordovician granitic rocks to the southeast. The mineralogy of the veins is complex; uranium, thorium, and the rare earths occur in several minerals from different parts of the veins. A total of 34 minerals has been recognized, although many are sporadically or locally distributed. The principal gangue minerals are quartz and albite. Uranium generally occurs in thorium-bearing uraninite, but it also found in brannerite. Thorite is the principal thorium bearing mineral in the northwest and central part of the vein system, but allanite is found in the southeastern part of the system. In addition to allanite, the rare earth minerals include bastnaesite, xenotime, monazite, and an unnamed mineral. The uranium content of 43 vein samples ranges from 0.005 to 2.8 percent; thorium content of 27 samples ranges from 0.0033 to more than 10 percent; and total rare earth content of 17 samples ranges from 0.023 to more than 10 percent. The distribution of the rare earths is unusual: one part of the vein may contain predominantly cerium-group rare earths, and another part of the same vein may yield predominantly yttrium-group rare earths. The I and L veins also contain abnormal amounts of beryllium, niobium, zirconium, barium, strontium, tin, lead, zinc, copper, and molybdenum. (Auth) (JMT)

<813>
Tessendorf, T.N., Reserve Oil and Minerals, Grants, NM

Redistributed Orebodies of Poison Canyon Mine. AAPG Bulletin 63(4):694-695. (1979, April)

Since the early 1950s Poison Canyon has been a classic example of uranium geology. At the present time, because of economic conditions, a closer examination of the redistributed mineralization is being made. Because of the evolution of the structure and geomorphology of Poison Canyon, the primary mineralization went through further oxidation and reduction. Enriched solutions of uranium migrated downdip through permeable sandstones, with calcium replacing silica near mudstone contacts. These solutions were controlled by north-trending fracture patterns, with some vertical movement along major faults. The uranium collected in structural and lithologic traps, then oxidized, forming amoebalike orebodies with the higher grade mineralization located in the fractures. The authigenic mineral is mainly tyuyamunite in the hexavalent state in sands deficient in carbon and associated, although rarely, with pascoite and ilsemannite. The equilibrium of the primary minerals differs from that of the redistributed minerals. The uranium has been leached from the primary minerals causing chemical values to be less than radiometric. The redistributed minerals are chemically greater than radiometric, producing a favorable equilibrium. Also, the percent extraction in the mill process is greater for the redistributed ore than the primary ore. The paragenetic position of the different minerals has a direct bearing on these observation. (Auth)

<814>
Tweto, O., and P.K. Sims, USGS, Denver, CO; Minnesota Geological Survey, Minneapolis, MN

Precambrian Ancestry of the Colorado Mineral Belt. Geological Society of America Bulletin 74:991-1014. (1963, August)

The narrow northeast-trending Colorado mineral belt, the site of most of the major mining districts of Colorado, is characterized by intrusive porphyries and associated ore deposits of Laramide age and, in some places by fissures and faults of northeasterly trend. The belt is about 250 miles long and extends diagonally across the generally north-trending mountain ranges of Colorado, occupying several different geologic environments and following an ancient zone of weakness defined by northeast-trending shear zones. Movement occurred along the shear zones through most of the Precambrian time. During this time, deformation progressed from a deep-seated environment characterized by folding and plastic flow to more shallow environment characterized by fracture and retrograde metamorphism. During Paleozoic and Mesozoic time, minor differential movements occurred repeatedly in the regional zone of shearing, as recorded by thinning, wedgeouts, and changes in facies of several sedimentary formations along the zone. With the onset of the Laramide orogeny, magma invaded the regional zone of shearing and imparted to it the conspicuous features that characterize the mineral belt - intrusive igneous bodies and ore deposits. Fault movement occurred along the zone at this stage also, but it was on a smaller scale than it had been previously. (JET)

Cited as a reference in NURE Contractor Reports.

URANIUM INDUSTRY

<415>
Norbaskas' Exploration Program Involves $100,000.
The Northern Miner 64(52):A3. (1979, March 8)

Norbaska Mines is concentrating its 1979 exploration program on a portion of its 14,000 acre Wollaston Lake property in Northern Saskatchewan. Five drill holes are to be put down as a first step in following up on the geophysical and radon surveys carried out over the past eight months. The program is expected to cost about 100,000 dollars. Exploration on the property is being directed by Norbaska under a joint venture agreement involving Norbaska (25 percent), Consolidated Reactor Uranium Mines (25 percent), and Saskatchewan Mining Development Corporation (50 percent). The company will also carry out further surface exploration on a second area in the northwest corner of the property, on Michael Lake, where reconnaissance geophysical surveys have established the presence of conductors. (JNT)

<416>
Rivkin and Company, Sydney, Australia

Prospects for the Uranium Industry in Australia.
INIS-mf-3277; 60 pp. (1976, February)

The report discusses basic issues of the coming uranium era the world supply and demand situation, the trend in uranium prices and the continuing move to nuclear power as the world's primary source of electrical energy. The first section of the report discusses the technical aspects of the nuclear industry but is necessarily brief because the real story is the world trend to nuclear power for economic and political reasons and the old story of supply and demand (discussed in section two). Within Australia some companies are better placed than others to benefit from the uranium era. Section three looks at prices and section four reviews the individual companies involved in the uranium industry in Australia. (PAC)

<417>
International Atomic Energy Agency, Vienna, Austria

Processing of Low-Grade Uranium Ores.
Proceedings of a Panel, Vienna, June 27 - July 1, 1966. International Atomic Energy Agency, Vienna; 247 pp. (1967)

The proceedings of a panel convened by the International Atomic Energy Agency in Vienna on the processing of low-grade uranium ores. Twenty-two specialists from 15 countries and one international organization attended the meeting and they were asked to make appraisals of the current situation with regard to the processing of low-grade uranium ores and give recommendations for a possible IAEA program of activities. These 13 status reports and 13 other technical reports are presented. Seven of the thirteen technical reports were abstracted for the NURE data base. (JNT)

<418>
Al-Shaieb, Z., and J.W. Shelton, Oklahoma State University, Department of Geology, Stillwater, OK

Uranium Potential of Sedimentary and Igneous Rocks in Western and Southwestern Oklahoma. USGS Circular 753; Short Papers of the US Geological Survey Uranium-Thorium Symposium, 1977, J.A. Campbell (Ed.), (pp. 61-62), 75 pp. (1977)

Uranium anomalies are present in Permian terrigenous clastic rocks and Cambrian igneous rocks in western and southwestern Oklahoma. These anomalies are known to occur in siltstones of the Doxey Formation, in the Post Oak Conglomerate near the Wichita Mountains, and in dikes within the igneous complex of the Wichita Mountains. A carnotite-tyuyamunite-bearing zone is localized in the lower part of the Doxey Formation. This formation is characterized by alternating siltstones, mudstones, and shale. The host rock is composed of highly resistive, well stratified, pale-reddish-brown sandy siltstone beds, 12-150 cm thick. Subangular to angular quartz and feldspar grains are cemented by secondary gypsum and calcite. Ripple marks and small-scale crossbedding are major sedimentary structures and the depositional environment of the Doxey is interpreted to be tidal-flat. Uranium occurs as spotty encrustations along bedding planes, as fillings of small fractures, and as part of the cement in siltstones. The mineralization appears to be spatially related to grayish-green siltstone and also to the secondary gypsum disseminated in siltstones and filling fractures. The Post Oak Conglomerate represents the uppermost Permian unit of a thick section of Pennsylvanian and Permian arkosic and carbonate detritus derived from the Wichita uplift. The conglomerate near the mountains consists of cobbles and boulders in a matrix of sandstone which displays may abrupt lateral and vertical changes in grain size. The Post Oak shows low uranium contents ranging from 2 to 8 ppm; averaging 2.3 ppm. The highest uranium values are found in sandstones which are characterized by a matrix of silt and clay, and which occur immediately south of granite outcrops. Uranium anomalies are also present in a coarse-grained, arkosic, channel sandstone 20 km south of the granitic rocks of the Wichita Mountains. The average uranium content of several samples is 60 ppm, however, no uranium minerals have been identified. Riebeckite aegirine pegmatite dikes, genetically related to the peralkaline Cambrian Granite, contain 40 to 100 ppm uranium. Fission tracks show that the uranium is associated with both ergirine-riebeckite and refractory minerals such as zircon and allanite. It is believed that uranium in these dikes is related to a late uranium-rich hydrothermal stage which followed an early magmatic phase. (JST)

<019>
Anderson, J.S., and M.I. Ritchie, Utah Construction and Mining Company

Solution Mining of Uranium. American Mining Congress Journal 54(1):20-26. (1968, January)

In early 1960, Utah Construction and Mining Co. started producing uranium ore from an underground mine in Shirley Basin, Wyoming. Because the costly square-set method had to be used in the mining, an investigation was initiated to determine what other production method could be used. The method selected for study was in situ leach mining. The most critical consideration in the solution mining at Shirley Basin was the pattern geometry. During the experimental phase, patterns were square or triangular, with the production well in the center. The area was bounded by inflow wells that were located irrespective of regional groundwater flow direction. During the early period of operation, nitric acid was used as a leaching agent. Analyses of uranium and nitrate recoveries for patterns mined during this phase indicated that solution losses were occurring and that there was substantial dilution in the effluent produced. In an attempt to correct these problems, a complete restudy was initiated, and pattern design was changed. The current design is based on the fact that interflow between wells in an aquifer having regional flow can be controlled by varying inflow-effluent rates, by distance between wells, and by aligning wells at specific angles to the direction of groundwater flow. Pattern operation starts with the introduction of the leaching solution to the three inflow wells. Sulfuric acid is now used instead of nitric acid. The uranium-bearing solution produced from the production wells is pumped into the recovery plant where two circuits, a continuous ion-exchange column with two attendant elution, or stripping columns and a fixed resin-bed column, extract the uranium. The resin column is then stripped with a mixture of nitric acid, sodium nitrate, and sulfuric acid, the solution is purified, and the U308 is precipitated with dolomitic lime or magnesium slurry. The outstanding advantages of the solution mining process are safety and relatively lo ost. The principal disadvantages of solution mining are the dependence on permeability and other uncontrollable ground conditions and the difficulty of getting acceptable recovery in multiple ore horizons. (JMT)

<020>
Civin, V., and J. Prochazka, Research and Development Laboratory No. 3 or the Uranium Industry, Prague, Czechoslovakia

Processing Uranium-Bearing Materials Containing Coal and Loam. Processing of Low-Grade Uranium Ores, Proceedings of Panel, Vienna, June 27 - July 2, 1966. International Atomic Energy Agency, Vienna, (pp. 89-95), 247 pp. (1967)

Among the ores which are classified as low-grade in the Cssr are mixtures of coal and bentonitic loam of tertiary origin, containing approximately 0.1 percent U and with a moisture content at times well above 20-30 percent. The uranium is held mainly by the carbonaceous component. Conventional processing of these materials presents various difficulties which are not easily overcome. During leaching the pulp thickens and frequently becomes pasty, due to the presence of montmorillonites. Further complications arise from the high sorption capacity of the materials (again primarily due to montmorillonites) and poor sedimentation of the viscous pulps. In addition, the materials are highly refractory to the leaching agents. The paper presents experience gained in solving the problems of processing these ores. The following basic routes were explores: (1) separation of the carbonaceous and loamy components: The organic component appears to be the main activity carrier. Processing the concentrated material upon separation of the inactive or less active loam may not only remove the thixotropic behaviour but also substantially reduce the cost of the ore treatment; (2) 'liquifying' the pulps or preventing the thickening of the pulp by addition of suitable agents; (3) joint acid or carbonate processing of the materials in question with current ore types; (4) removal or suppression of thixotropic behaviour by thermal pretreatment of the material; and (5) application of the 'acid cure' method. The first method appears to be the most effective, but it presents considerable difficulties due to the extreme dispersion of the carbonaceous phase and further research is being carried out. Methods 2 and 3 proved to be unacceptable. Method 4, which includes roasting at 300-400 degrees C, is now being operated on an industrial scale. The final method has also shown definite advantages for particular deposits of high montmorillonite content material.

<021>
Dare, W.L., Bureau of Mines, Denver, CO

Mining Methods and Costs - Continental Uranium, Incorporated, Continental Number 1 Mine, San Juan County, Utah. Bureau of Mines Information Circular 7801; 20 pp. (1957, September)

The Continental No. 1 mine is at the south end of the Big Indian mining district, San Juan County, Utah. The mine is on a school section owned by the State of Utah and leased by Continental Uranium, Inc. A 70,000-ton uranium-vanadium ore deposit was discovered as a result of an exploratory drilling program completed in 1954. The ore body is elongated along the east-west strike of the Moss Back member of the Triassic Chinle Formation. It is roughly tabular in shape, but irregular in outline. It dips 8 to 10 degrees to the south. The ore occurs at the base of the Moss Back, within 2 feet of the Permian Cutler Formation. The ore mined to date has an average thickness of about 7 feet. It is developed by a 350-foot slope and haulageway given within the ore stratum and mined by open stoping with random pillar support. The height of the ore, its gentle dip, and the strength of the overlying rock have permitted use of trackless loading and haulage equipment. (JMT)

<422>
Darnley, A.G., Canada Geological Survey, Ottawa, Ontario, Canada

New and Recent Results from the Canadian Uranium Reconnaissance Program. USGS Circular 753; Short Papers of the US Geological Survey Uranium-Thorium Symposium, 1977, J.A. Campbell (Ed.), (pp. 63-64), 75 pp. (1977)

The Geological Survey of Canada (GSC) was involved in developing new methods of exploration for uranium throughout the 1960's and is presently involved in an effort to delineate all regions in Canada where the crust contains an above normal amount of uranium. The uranium reconnaissance program primarily depends upon airborne gamma-ray spectrometry and regional geochemistry, but other methods are not excluded if these serve the objectives of the program. The objectives of the program are (1) to provide the mineral industry with high quality reconnaissance data to indicate those areas of Canada where there is the greatest possibility of finding new uranium deposits, and (2) to provide government with systematic and nationally consistent data to serve as a base for uranium resource appraisal. The program is expected to continue at least until 1985. Airborne gamma-ray spectrometry is primarily undertaken over relatively flat areas where there is some rock outcrop and generally thin overburden. Regional geochemistry is the only method being used at present in mountainous areas, but it is also being used in parts of the country with extensive overburden and in areas considered particularly favorable for uranium occurrence. (JRT)

<423>
Dickinson, K.A., USGS, Denver, CO

Uranium and Thorium Distribution in Continental Tertiary Rocks of the Cook Inlet Basin and Some Adjacent Areas, Alaska. USGS Circular 753; Short Papers of the US Geological Survey Uranium-Thorium Symposium, 1977, J.A. Campbell (Ed.), (pp. 70-72), 75 pp. (1977)

The Cook Inlet Basin area of Alaska contains a large thickness of continental sedimentary rocks containing carbonaceous material that could act as host rocks for uranium deposits and surrounding the area are suitable uranium source rocks in the form of granite and tuff. A study was conducted concerning the distribution of uranium in the potential host rocks to see if the uranium has been mobilized by dissolution, transported, and redeposited. A total of 57 samples of the potential host rocks were sampled with the uranium and thorium being determined by the delayed-neutron method of analysis. The uranium and thorium contents found in the continental sedimentary rocks of the Cook Inlet were very uniform. The uranium content averaged about 2.4 ppm and the range was from 0.5 to 4.3 ppm. The Th/U ratio averaged 2.3; low when compared to the general terrestrial rock ratio of 3-4, and low when compared to many oxidized nonmarine sedimentary rocks that characteristically have ratios of more than 7. The low uranium content and the low Th/U ratio found in the Tertiary sedimentary rocks of the Cook Inlet area may indicate that geochemical conditions have not been favorable for the formation of epigenetic uranium deposits, but it is important to note that the samples collected and analyzed for this report may not adequately represent the large amount of potential host rocks. (JRT)

<424>
Duncan, D.W., and A. Bruynesteyn, British Columbia Research

Microbiological Leaching of Uranium. New Mexico State Bureau of Mines and Mineral Resources Circular 118; Selected Papers from 1970 Uranium Symposium at Socorro, New Mexico, P.J. Rowan and D.M. Baker, Jr., Compilers, (pp. 55-61), 61 pp. (1971)

In the Elliot Lake area, uranium occurs primarily in the mineralized forms of uraninite and brannerite. Acid mine waters containing significant levels of soluble uranium were determined to also contain the iron- and sulfide-oxidizing bacteria, THIOBACILLUS FERROOXIDANS. The production rates for the mine were cyclic due to the bacterial leaching being favored by the moisture-laden air of summer and inhibited by the loss of moisture during the winter months. The enhancement of bacterial activity was determined to be promoted by microbiological oxidation of ferrous iron and pyrite. Energy released during these oxidation steps is used for growth by the bacterium. The leaching area should be damp, within the pH range of 2 to 3, adequately ventilated, phosphate and ammonium sulfate available to the bacteria, and the temperature at about 35 degrees C. Production on the commercial scale should be increased where stopes meet these requirements. (PLG)

<825>

[illegible]

<825>
El Shazly, E.M., M.A.T. El Hazek, and I.H. Zayed. UAR Atomic Energy Establishment, Cairo, United Arab Republic

Leaching Experiments on Uraniferous Shales and Sandstones from Qatrani, Western Desert, United Arab Republic. (1971)

The Qatrani uraniferous shales are characterized by the presence of clays, particularly montmorillonite associated with dolomite and calcite, gypsum, hematite and goethite, humic organic matter, quartz sand, native sulfur, some feldspars altered to sericite, soluble salts and other minor minerals, all in variable amounts. Leaching experiments were carried out on a shale with a uranium content of 240 ppm. Physical methods of concentration, including sieving, magnetic separation, heavy-liquid separation, tabling, and flotation failed to make fractions with a higher uranium content than the original shale. Direct alkaline leaching was not promising owing to the high consumption of sodium carbonate due to the presence of gypsum and organic matter: also uranium extraction is not possible in this medium, and sodic decomposition was not feasible due to the decomposition of uranium. It was found that the recovery of uranium could be effected through methyl alcohol precipitation of uranium and sodium sulfate, redissolving it a minimum of water followed by sodic decomposition with soda. Direct acid leaching was not promising because of the high acid consumption caused by the abundance of carbonates and the presence of organic matter. The acid process was improved by roasting followed by slaking and then leaching with sulfuric acid and ultimately recovering uranium by anion-exchange resin IRA 400. The red ferruginous sandstone of Quatrani is constituted of quartz sand with hematite and goethite associated with a small amount of dolomite. Experiments carried out on a sandstone containing 266 ppm uranium indicated that uranium leaching is mainly connected with the dissolution of the iron oxides. Hydrochloric acid was found to be the best acid for leaching, while the addition of an oxidant (NaO2) was necessary for the process. (Auth) (JET)

<826>
Fisher, J.R., Rio Algom Mines Limited, Research and Development Department, Mining Division, Elliot Lake, Ontario, Canada

Bacterial Leaching of Elliot Lake Uranium Ore. Canadian Mining and Metallurgical Bulletin 59(649):580-592. (1966, October)

The uranium mines in the Algoma District in the area of Elliot Lake, Ontario, contain ore of the pebble conglomerate type. The uranium mineralization, along with 4 to 6 percent sulfides, occur in the matrix interstitial to the pebbles. In 1959, it was found that the pH of the mine waters in some of the mines was decreasing and becoming more acidic with time. As the pH of the waters became more acidic, the uranium content of the waters increased. The general trend was that the pH of the mine waters would slowly decrease to about 4.5 over a period of 4 to 6 years. The decrease in pH would then drop suddenly to about 2.5 in a matter of months. In 1961, a research program was begun to determine the cause of the increased acidity of the mine waters, and it was found that the bacterium, THIOBACILLUS FERROOXIDANS, was the cause of the decrease in pH. THIOBACILLUS FERROOXIDANS has the property of producing ferric iron, which caused the mine waters to become oxidizing, allowing the hexavalent uranium to be oxidized and thereby making it completely soluble in the sulfuric acid which is formed from the reaction between the oxidizing mine water and the sulfides present in the ore. In August, 1964, following the shut down of Rio Algom Mines Limited conventional mining and milling system at the Milliken mine, a research program was begun to evaluate the practicality of leaching uranium via bacterial action. A series of drill holes were directed through the parting wall of the Milliken mine and the Lacnor mine, which had been previously shut down. The bacterial activity in the mines resulted in a coating of basic ferric sulphate on the rocks in the mine. High pressure hoses were used to remove the coating and free the soluble uranium. After washing the stopes, a 80 pound bag of bacterium nutrient known as 9K was spread on the stope floor. After 160 days, the 9K nutrient was found to give an 86 percent U308 extraction rate compared to a 66 percent rate when no nutrient was used. The nutrient was spread at about 3 grams per square foot of stope floor area. Over a period of 1 year, 127,000 pounds of uranium were recovered from the underground workings of the Milliken mine by the use of bacterial leaching. The over-all grade of the water being pumped to the surface was 0.135 g/l, or 1.35 pounds per 1000 gallons of water treated. During the operation, it was discovered that the bacterium requires at least a temperature of 18 degrees C to obtain good results. During the winter of 1964-65, the underground rock temperatures in parts of the Milliken mine dropped to 18 degrees C and this decrease in temperature reduced bacterial activity by 30 to 40 percent when compared to the summer activity. (JET)

<827>
George, D.R., and J.R. Ross, Salt Lake City Metallurgy Research Center, Salt Lake City, UT

Recovery of Uranium from Uranium Mine Waters and Copper Ore Leaching Solutions. Processing of Low-Grade Uranium Ores, Proceedings of a Panel, Vienna, June 27 - July 1, 1966. International Atomic Energy Agency, Vienna, (pp. 227-234), 287 pp. (1967)

Waters pumped from uranium mines in New Mexico are processed by ion exchange to recover uranium. Production is approximately 200 lb U308/day from waters containing 5 too 15 ppm U308. Recoveries range from 80 to 90 percent. Processing plants are described. Uranium has been found in the solutions resulting from the leaching of copper-bearing waste rock at most of the major copper mines in the western United States. These solutions, which are processed on a very large scale for recovery of copper, contain 2 to 12 ppm U308. Currently, uranium is not being recovered, but a potential production of up to 6000 lb U308/day is indicated. Ion exchange and solvent extraction research studies are described. (Auth)

<028>
Groth, F.A., The Colorado Corporation, Denver, CO

Day Sandstone Uranium Deposit in the Battle Spring Formation, Lost Soldier-Green Mountain Area, Sweetwater County, Wyoming. Wyoming Sandstone, R.L. Enyert (Ed.), Proceedings of the 22th Field Conference, 1970. Wyoming Geological Association, Casper, WY, (pp. 9-12), 292 pp. (1970)

In 1969 the Colorado Corporation undertook a drilling project of uranium leases and claims covering 25,000 acres in the Lost Soldier-Green Mountain area, Sweetwater County, Colorado. As a result, uranium was discovered in the lower part of the Battle Spring formation, a Tertiary unit consisting of sandstone, conglomerate and shale. The occurrence of the Lost Soldier uranium deposit is initially related to the lithofacies development along the Muddy Gap paleodrainage; these deposits were then supergenely distributed and/or enriched in their present positions. The site of mineralization appears to be controlled by oxidation, stratigraphy, and structure. ([illegible])

<029>
Guimond, R.J., and S.T. Windham, USEPA, Office of Radiation Programs, Washington, DC

Radioactivity Distribution in Phosphate Products, By-Products, Effluents, and Wastes. ORP/CSD-75-3; 32 pp. (1975, August)

Samples of phosphate ores, products, by-products, effluents, and wastes from several mines, wet process phosphoric acid plants, and electric furnace facilities throughout the southern US were analyzed for U, Ra 226, and Th. Ra 226 analyses were performed using the Rn emanation method; U and Th were detected by alpha spectroscopy after ion exchange concentration and coprecipitation. Only data from Florida are presently available; analysis of marketable rock showed 42 pCi/g Ra 226, 41 pCi/g U 234, 1.9 pCi/g U 235, 41 pCi/g U 238, 2 pCi/g Th 227, 0.61 pCi/g Th 228, 42.3 pCi/g Th 230, and 0.44 pCi/g Th 232; slimes contained 45, 42, 2.6, 40, 2.3, 1.2, 40, and 1.4 pCi/g, respectively; sand tailings has 7.5 pCi/g Ra 226, 5.2 pCi/g U 234, 0.30 pCi/g U 235, and 5.3 pCi/g U 238. Approximately 60 percent of the activity extracted in Florida phosphate mining remains as waste products after beneficiation; removal of suspended solids from the heavy slime before effluent discharge removes 92-99.9 percent of the Ra in the slimes. Analyses of effluents from seven mine and beneficiation plants found no Ra 226 discharge greater than 2.0 pCi/l. In wet process phosphoric acid production most of the Ra 226 remains with the phosphogypsum by-product, while most of the U and much of the Th enter solution and are transferred to the phosphoric acid product. Lime neutralization of effluents was found to be very effective in removing Ra 226, U, and Th 230. In the electric furnace process, most of the Ra 226 is retained in the calcium silicate slag; this may not be true of other radionuclides, such as Po 210, that may be volatilized in the furnace. Increased emphasis on assessing the potential impact of gypsum and slag by-products is recommended. The radioactivity concentrations in raw materials, products, wastes, by-products, and effluents detailed in this paper should enable additional work to model migration pathways of these radionuclides in the environment and to estimate individual and overall population impacts. ([illegible])

<030>
Hathaway, L.R., Kansas Geological Survey, Lawrence, KS

Interpretation of Uranium Content of Ground Water in West-Central Kansas. USGS Circular 753; Short Papers of the US Geological Survey Uranium-Thorium Symposium, 1977, J.A. Campbell (Ed.), (pp. 65-66), 75 pp. (1977)

The uranium content of ground water collected from 239 pumping irrigation wells was determined by X-ray fluorescence. Ground water from these wells was derived from (1) the Ogallala Formation (Tertiary), (2) undifferentiated Tertiary (Ogallala) and Quaternary sequences, and (3) Quaternary alluvial sediments along the Arkansas River in the west-central area of Kansas. The bedrock formations from north to south (Pierre Shale to Dakota Sandstone) increase in age from Late to Early Cretaceous. The water table slopes regionally from west to east, and the water varies from an alkaline earth-bicarbonate type to an alkaline earth-sulfate type. Uranium concentrations ranged from 2-172 ppb, with a mean of 14 ppb. The areal distribution of waters with uranium levels above 20 ppb was closely related to a north-south-trending topographic depression (Scott-Finney depression and Scott Basin) that is also reflected in bedrock contours, and to portions of the Arkansas River valley. These areas contain saline soils and shallow water tables, and usually exhibit sulfate-type ground water and higher total dissolved solids content. In the Scott Basin area the higher total dissolved solids level in the ground water appears to be related to leaching of soluble salts from the soils in the basin area. Water from the sandy areas south of the Arkansas River exhibits low uranium levels. Several major chemical species and the total dissolved solids in the ground water show a positive correlation with uranium, which suggest the higher uranium values observed may result from an increased salt loading of soils and ground water in areas of shallow water tables. Correction for common correlation with total dissolved solids is found to reduce greatly the number of variables exhibiting a significant correlation with uranium (SiO_2, F, Sr, and Mg). A comparison of uranium content with total dissolved solids suggested that water from the Scott Basin, some of the upland drainage areas, and the northern half of the Scott-Finney depression exhibit a higher uranium-to-total-dissolved-solids ratio than water from the southern half of the depression and the alluvium of the Arkansas River valley. This comparison also suggest that waters having two different compositions, both with relatively high uranium contents, exist in the area. The relatively high uranium content of ground water from this area suggested that a regional anomaly exists for the aquifer and related systems in the Ogallala. Such an anomaly may result from leaching and dissolution of volcanic ash found in the Ogallola that contains about 6 ppm uranium. (JWT)

<831>
Hayslip, D.L., G.E. Fuller, P.W. Levy, and J.R. Renault, Brookhaven National Laboratory, Upton, NY; New Mexico State Bureau of Mines and Mineral Resources, Socorro, NM

Thermoluminescence of Uranium Host Rocks in Ambrosia Lake Area. AAPG Bulletin 63(4):689. (1979, April)

Exposure to radiation during the formation or redistribution of uranium ore deposits is expected to affect the thermoluminescence (TL) properties of the host rock. For example, TL measurements on samples from a traverse of a Wyoming roll-type deposit display the following intensity-versus-distance pattern. Starting from barren oxidized ground the intensity increases gradually with decreasing distance to ore, is extremely high in ore, and drops abruptly with distance in reduced ground to a level substantially below that in oxidized ground. This pattern is in accord with current hypotheses concerning the genesis of this type of deposit. Measurements of both natural and artificial TL made on quartz separates from drill cores and samples collected underground in the Ambrosia Lake area, because of the intensity and structure of their respective glow curves, permit discrimination among oxidized ground, reduced ground, and mineralized areas. In addition, samples from oxidized ground show TL intensities and glow-curve characteristics that have been correlated with structural features that controlled the redistribution of ore. Although the data show some statistical variation, the general intensity-verses-distance pattern has been observed in many cases. All currently available results suggest that TL can be developed into a viable tool for uranium exploration.

<832>
Heide, E.A., M. Paschke, K. Wagener, and M. Wald, Kernforschungsanlage Julich GmbH, Julich, Germany

Matrix of Cultivable Mutants of Single - Celled Green Algae and Process for Obtaining Uranium by this Matrix. ORNL-tr-4220; 2 pp.; German Federal Republic Patent DT-23-45-430-A1. (1975)

A technique is proposed for the extraction of uranium from seawater by mutated unicellular green algae. The mutants are formed by irradiation green algae with about 50 kR of x-rays and culturing them on a nutrient substrate enriched in U. Surviving colonies are cultivated further in the usual way, and strains particularly suited to U-enrichment are selected. A massive culture is placed in a filter cage with at least two walls made of sieves permeable to seawater but not to the algae. This filter cage may be placed so that water is swept through it by tidal action. With an algal cell size of 50-100 u and a sieve more size such that total cross-sectional area of the matrix is 100 square mile, a flow rate of 10(E+6) tons of seawater per day should be attainable. U is removed from the matrix by tributyl phosphate extraction. (LKH)

<833>
Hill, J.P., Texas Railroad Commission, Austin, TX

Responsibilities of Texas Railroad Commission for Uranium Mining Persuant to Surface Mining and Reclamation Act of 1975. AAPG Bulletin 63(3):466. (1979, March)

The Texas Surface Mining and Reclamation Act was enacted on June 21, 1975, with the expressed intent of regulating the surface mining of coal and uranium and activities associated with a surface mining operation. The Railroad Commission of Texas has certain responsiblities pursuant to this legislation, although some types of activities are not affected by this law. (Auth)

<834>
Huang, W.H., Texas A & M University, College Station, TX

Uranium Deposits of Texas Gulf Coastal Plain - Trend, Exploration, and Production. AAPG Bulletin 63(3):470. (1979, March)

Uranium in the Texas Gulf coastal plain occurs primarily in two types of deposits: (1) in sandstone-type deposits of Goliad, Oakville, Catahoula, Frio, and upper Jackson, and (2) in Tertiary Wilcox, Yegua-Jackson, and upper Jackson lignite. Total potential resources of uranium in the coastal plain have been estimated to be about 0.25 million tons, ranking third in the United States. Analyses of several thousand samples from the coastal plain show the following results. (1). In the sandstone-type deposits, uranium is both roll type and nonroll type. Most uranium concentrates are in reduced ores. Uranium is closely associated with (a) lignite or disseminated organic matter, (b) clays, particularly smectite, (c) zeolites, particularly with clinoptilolite, and (d) carbonate rocks and calcite. Uranium minerals present are uraninite, coffinite, carnotite. Adsorption of uranium by clays is largely dependent on pH. (2). In lignite, the concentration of uranium decreases with geologic age. Uranium is generally concentrated at the contacts of lignite seams with sandstones or shales rather than in the middle of the seam. Recovery of uranium has been either by surface or in-situ mining. However, development of in-situ leaching has gained new impetus because of the unique situation of south Texas uranium deposits. Results of laboratory tests show that hydrochloric acid is the most effective solvent to recover uranium from either oxidized or reduced sandstone-type ore deposits, and from lignite without the addition of oxidant (e.g., H_2O_2). (Auth)

<835>
Kelly, T.E., R.L. Link, and M.R. Schipper, Geohydrology Associates, Inc., Albuquerque, NM

Effects of Uranium Mining on Groundwater in Ambrosia Lake Area, New Mexico. AAPG Bulletin 63(4):690. (1979, April)

The principal ore-bearing zone in the Ambrosia Lake area of the Grants uranium district is the Westwater Canyon Member of the Morrison Formation of Jurassic age. This is also one of the major artesian aquifers in the region. Significant declines in the potentiometric head within the aquifer have been recorded, and digital modeling shows that declines may locally approach 3,000 ft (900 m) in the vicinity of a mine. Loss of potentiometric head in the Westwater Canyon Member has resulted in the interformational migration of groundwater along fault zones from overlying aquifers of Cretaceous age. This has resulted in local deterioration in chemical quality of the groundwater. (Auth)

<436>
Kennedy, R.H., Atomic Energy Commission,
Washington, DC

Recovery of Uranium from Low-Grade Sandstone Ores and Phosphate Rock. Processing of Low-Grade Uranium Ores, Proceedings of a Panel, Vienna, June 27 - July 1, 1966. International Atomic Energy Agency, Vienna, (pp. 216-226), 247 pp. (1967)

Commercial-scale experience in the United States in the recovery of uranium from low-grade sources is discussed. The majority of the uranium recovery operations have been conducted by operators of uranium mills as an alternative to processing normal-grade ores. The operations have generally been limited to the treatment of low-grade materials generated in the course of mining normal-grade ores. In some circumstances such materials can be treated by simplified procedures as an attractive source of additional production. The experience gained in uranium recovery from phosphate rock is treated in some detail. The land pebble phosphate rock of central Florida generally contains about 0.01 to 0.02 percent U3O8. While no uranium is being recovered from this source at the present time, it does represent a significant potential source of by-product uranium production because of the large tonnages being mined. (Auth) (JHT)

<437>
Larson, W.C., Bureau of Mines, Twin Cities, MN

Uranium IN SITU Leach Mining in the United States. Bureau of Mines Information Circular 8777; 68 pp. (1977)

A broad overview of this relatively new mining technology is given, and the purpose of the report is as a reference source for information on IN SITU leaching. A list of IN SITU leaching publications is included as well as engineering data tables for almost all of the active pilot-scale and commercial uranium IN SITU leaching operators. Additional information is given that discusses the current Bureau of Mines uranium IN SITU leaching research program. (JHT)

This report contains 259 references concerning IN SITU leach mining.

<438>
Larson, W.C., Bureau of Mines, Twin Cities, MN

Uranium In-Situ Leach Mining - A Third Alternative. AAPG Bulletin 63(3):486. (1979, March)

Uranium in-situ leach mining, when used as a single commercial mining method, represents a technologic breakthrough with which many people are not familiar. In the last 5 years, plant-installed capacities for uranium in-situ leach mining have increased approximately 12-fold. There are now at least seven western states which have activities of some type regarding uranium in-situ leaching. (Auth)

<439>
Lapirov, A.P., State Committee for the Utilization of Atomic Energy, Moscow, USSR

Underground Leaching - A Method for the Economic Extraction of Uranium from Low-Grade Ores. Processing of Low-Grade Uranium Ores, Proceedings of a Panel, Vienna, June 27 - July 1, 1966. International Atomic Energy Agency, Vienna, (pp. 210-215), 247 pp. (1967)

The method of underground leaching of uranium ores has a number of advantages over extraction followed by processing of the ores in factories. It has been studied in two types of deposits, occurring in rock masses and sandy shales. Research techniques were worked out accordingly for the leaching of uranium from large-grained ore (-200 mm) and from layers in natural stratification. Special models were constructed permitting the simulation of underground leaching conditions. The results obtained were checked in field conditions on experimental plots and experimental underground blocks. The investigations demonstrated the practicability of the process of underground leaching of uranium from certain ores and made it possible to work out flow-sheets and routines for an industrial process, information about which is given in the paper. (Auth)

<440>
Mashbir, D.S., Western Nuclear Inc., Metallurgical and Chemical Department, Jeffrey City, WY

Heap Leaching of Low Grade Uranium Ore. Mining Congress Journal 50(12):50-54. (1964, December)

Two basic heap leaching methods are used by Western Nuclear, Incorporated for extracting uranium from low grade ores. They are referred to as conventional (straight gravitational down-flow through an open pile) and percolation (controlled flow, both upward and downward, through a contained pretreated pile) leaching. The conventional heap leaching method consists of applying dilute sulfuric acid solutions to open or exposed piles of low grade uranium ore, and recovering the leach solutions. At the Gas Hills, the U3O8 recovery was 89.2 percent. The percolation leaching method involves leaching crushed ore in a tank specially constructed for that purpose. This process has a 91.4 percent recovery rate. Both leaching processes allow the large amounts of waste ore below the mine cut-off grade to be economically processed. (JHT)

<441>
Matthews, D.C., Anaconda Company

Hydrometallurgical Aspects of Mineral Exploration. 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. 1-2), 61 pp. (1971)

Hydrometallurgy may incorporate such preparational procedures as boring into a mineral deposit for in situ leaching, blasting or ripping for heap leaching, crushing for vat leaching, and grinding for agitation leaching. Uranium deposits determined to be uneconomical to process must be analyzed by hydrometallurgical processes. Exploration must give due consideration to proposed mining methods in regard to selectivity and/or separation of the ores into metallurgical intervals and provide ample samples for the metallurgist to blend and composite to simulate potential mill feeds. (PAG)

<442>
Maysilles, J.H., L.L. Nichols, and D.C. Seidel,
Bureau of Mines, Washington, DC

Extracting Uranium from a Wyoming Granite.
Bureau of Mines Report of Investigations 8219; 15
pp. (1977)

A possible future source of uranium is granitic material. The Bureau of Mines, in an effort to explore the general leaching characteristics of such potential resources, leached samples of Wyoming granite that contained 0.06 to 0.12 percent U3O8. Conventional acid leaching extracted 93 percent of the uranium in 18 hours. The amount of required acid addition was 50 to 100 pounds of H2SO4 per ton of ore, and the oxidant addition was 3 pounds of NaClO3 per ton of ore. The acid consumption continues after maximum uranium recovery has been reached; this effect may complicate heap or in situ leaching with acidic solutions. Some variation in reagent requirements was noted between the two ore samples. Conventional carbonate leaching with strong solutions at 85 degrees C extracted 94 percent of the uranium in 24 hours. These granitic materials also showed some response to dilute carbonate solutions, and the results suggest that the material may be chemically amendable to heap or in situ leaching with dilute carbonate solutions. (Auth) (JHT)

<443>
McCreedy, H.H., V.F. Harrison, and W.A. Gow,
Canada Department of Energy, Mines and Resources,
Mines Branch, Extraction Metallurgy Division,
Ottawa, Ontario, Canada

A Proposed Method, Using Bacteria, for the
Continuous Leaching of a Uranium Ore. Canadian
Mining and Metallurgical Bulletin
62(682):135-140. (1969, February)

A semi-continuous bench-scale, countercurrent-decantation system, in which the ore was moved countercurrently to the flow of leaching solution, was used to conduct acid-leaching tests on uranium ore with the aid of bacteria. The method, which involved a low degree of agitation, was successfully applied to extract uranium in practical amounts and at practical rates. The acidity of the leaching solution was the main variable investigated in the bench scale tests done in the Mines Branch. Over 90 percent of the uranium was extracted in a six-stage system. The results suggest that this technique could be applied in the utilization of bacterial oxidation and leaching as a method for treating Elliot Lake uranium ore. (Auth)

<444>
Mertie, J.B., Jr., USGS, Reston, VA

Monazite Placers in the Southeastern Atlantic
States. USGS Bulletin 1390; 41 pp. (1975)

Placer mining for monazite in North and South Carolina during the periods 1887-1911 and 1915-1917 was done on small deposits in the headwaters of streams that drained monazite-bearing rocks. Exploration was undertaken in 1951-1954 by the USGS and the US Bureau of Mines with the objective of finding larger ore bodies of suitable grade downstream that would warrant large-scale mining. Such deposits have not been found and the explanation for the lack of deposits is that a high percentage of alluvial monazite moves continuously downstream unless it can be held in the interstices of gravel beds. Because weathering of most common crystalline rocks in the Southeast generally yields only sand, silt, and clay, alluvial sediments contain only sparse gravel deposits. The part of the Coastal Plain most likely to have detrital monazite from the belts of monazite-bearing crystalline rocks in the Piedmont lie in the state of Virginia, North Carolina, South Carolina, Georgia, and Florida. The formations of the Coastal Plain range in age from Cretaceous to Holocene. Distinct Pleistocene terraces are present. The occurrence of monazite in the sedimentary formations of the Coastal Plain in economic quantities is considered unlikely, but reconcentrations of such deposits by local streams may yield workable placer deposits. A fluvial deposit in Aiken County, S.C. is cited and described as an example of this process. Pleistocene terraces, whose upper limits mark ancient shorelines have been correlated with several interglaciations of the Pleistocene Epoch, and conditions of weathering, erosion, transportation, and deposition of these sediments were more favorable for the accumulation of heavy minerals than in Holocene time. Because of this, the largest volume of heavy minerals will be found in terrace deposits, rather than along present beaches. Monazite is also generally distributed in all the littoral deposits of Florida, but the content is too low to produce monazite placers. Placers of ilmenite, rutile, and zircon, however, are mined, and at two of the four operating plants, monazite is produced as a by-product. (JHT)

<445>
Nelson-Moore, J.L., D.B. Collins, and A.L.
Hornbaker, Colorado Geological Survey, Denver, CO

Radioactive Mineral Occurrences of Colorado and
Bibliography. Colorado Geological Survey
Bulletin 40; GJBX-5(79); 1054 pp. (1978)

The two-part report provides and essentially complete listing of radioactive occurrences in Colorado, with a comprehensive bibliography and bibliographic cross-indexes. Part 1 lists approximately 3000 known radioactive occurrences with their locations and brief accounts of the geology, mineralogy, radioactivity, host rock, production data, and source of data for each. The occurrences are classified by host rocks and plotted on USGS 1 degree x 2 degree topographic quadrangle maps with a special 1:100,000-scale base map for the Uravan mineral belt. Part 2 contains the bibliography of approximately 2500 citations on radioactive mineral occurrences in the state, with cross-indexes by county, host rock, and the special categories of "Front Range", "Colorado Plateau", and "thorium". The term "occurrence" as used in this report is defined as any site where the concentration of uranium or thorium is at least 0.01 percent of where the range of radioactivity is greater than twice the background radioactivity. All citations and occurrence data are stored on computer diskettes for easy retrieval, correction, and updating. The US Geological Survey and the US Department of Energy provided the largest volumes of both bibliographic and occurrence data. Additional sources included private mining and exploration companies working in Colorado, State agencies, and various published and unpublished reports. (Auth) (PAC)

<446>
Riese, A.C., and C.J. Popp, New Mexico Institute of Mining and Technology, Socorro, NM

Application of Solution-Mineral Equilibrium Chemistry to Solution Mining of Uranium Ores. AAPG Bulletin 63(4):693. (1979, April)

Modern methods of solution mining are typically accompanied by gains and losses of mass via reagent consumption by rock-forming minerals and subsequent clay-mineral formation. A systemic approach to alleviation of such problems involves the application of leach solutions which are in equilibrium with the host rock minerals but in disequilibrium with the ore-forming minerals. This steady state can be achieved by solution composition adjustments within the systems K2O-Al2O3-SiO2-H2O and Na2O-Al2O3-SiO2-H2O. Uranium ores from the Grants mineral belt of New Mexico containing 0.15 to 1.0 percent U3O8 were collected for investigation. Small-scale (less than or equal to 1 kg) column leaching experiments have been conducted to compare results of conventional leaching systematics with those obtained with solutions in equilibrium with the matrix minerals. Application of these principles will have considerable bearing on future in-situ leaching of uranium ores. (Auth)

<447>
Rutledge, C., Wyoming Mineral Corporation, Lakewood, CO

In-Situ Uranium Solution Mining - Environmental and Licensing Regulations. AAPG Bulletin 63(3):519. (1979, March)

Under changing conditions, the structure of state or federal regulatory agencies, their resources and authority, and their people and how they function also are subject to changing responsibilities. Similarly, a typical vigorous mining corporation utilizing newly developing technology changes with respect to its organization and objectives, its employees and their attitude, plus the economic principles and competition which motivate the company's method of operation. The interaction of the government agency and the firm finds concomitant changes in the outcome of the divergent forces and demands on each. Of particular importance are the provisions of rules, regulations, and permits produced under these circumstances, as well as the company's responses to them. (Auth)

<448>
Santos, E.S., R.B. Hall, and P.C. Weisner, USGS, Denver, CO

Mineral Resources of the San Pedro Parks Wilderness and Vicinity, Rio Arriba and Sandoval Counties, New Mexico. USGS Bulletin 1385-C; 29 pp. (1975)

A study of the San Pedro Parks Wilderness was made by the USGS and the US Bureau of Mines from 1970 to 1972. Included in the study were investigations of mining claim locations within and adjacent to the wilderness, investigations of the present status of the mineral industry in the general region, and a field evaluation of all known mining claims and prospect workings. During the 1950's and early 1960's, numerous uranium claims were staked on the Cutler Formation and younger strata adjacent to the wilderness. Two small shipments of mineralized rock were made from the mill at Shiprock, New Mexico, but no payment was made for either shipment due to the low grade of the rock. The results of the investigation into the mineral resources of the San Pedro Parks Wilderness indicated that there are no exploitable mineral deposits, fossil fuels, or geothermal energy resources. (JHT)

<449>
Sugier, P., Direction des Productions, CEA, Chatillon-Sur-Bagneux, France

Recovery of Uranium in Mine Waters. Processing of Low-Grade Uranium Ores, Proceedings of a Panel, Vienna, June 27 - July 1, 1966. International Atomic Energy Agency, Vienna, (pp. 96-100), 247 pp. (1967)

In a brief introductory survey the author indicates the data on which leaching was first observed in the CEA mines and lists the main factors necessary for, or favourable to, the solubilization of uranium in mines. Information is given on the various sources of this type at present identified in France and the methods used to recover uranium in mines situated near ore-concentration plants. An explanation is given for the use of the calcium precipitation technique in connection with waters produced in mines not situated near ore-concentration plants. Data are given on the results of laboratory tests carried out on waters containing uranium, together with a description of an industrial-scale facility built in consequence of these tests. Details are given of the statistical results obtained. The author concludes by outlining the programme which will be implemented in the near future with a view to increasing the tonnage of uranium produced by in situ leaching and indicated that the CEA engineers are very optimistic about the prospects of this new low-cost method of producing uranium. (Auth)

<450>
Tweeton, D.R., and K. Connor, Bureau of Mines, Twin Cities, MN

Well Construction Information for In Situ Uranium Leaching. Bureau of Mines Information Circular 8769; 19 pp. (1978)

This publication describes present practices of making injection wells for in situ uranium leaching. Casings, screens, drilling fluids, coring, logging, cementing, and developing are discussed with the objective of aiding those who are starting an in situ leaching operation. Improper choices of materials or techniques can result in wells that are either useless or wells that have an undesirably high resistance to injection. Important factors include careful selection of screen slot size, use of logs for choosing the cementing basket depth, proper cementing techniques, and careful choice, use, and flushing of drilling fluids. The information was obtained through observation of well construction and through discussion with in situ leaching companies, drillers, and suppliers. (Auth)

<451>

URANIUM INDUSTRY

<451>
Vitunski, S., The Northern Miner, Toronto,
Ontario, Canada

Nuclear Scare Knocks Down Wide Range of Uranium Stocks. The Northern Miner 65(4):1, 16. (1979, April 5)

The Three Mile Island nuclear power plant accident may affect companies engaged in exploration and mining for uranium. Although it appears certain that nuclear energy will be increasingly important in the future, resistance to power plants and more stringent regulation will undoubtably result in a longer lead time in the construction of new plants. The potential slowing of the growth of the entire nuclear industry may affect uranium exploration and the development of mines considerably if the demand for uranium falls. (JMT)

<452>
Blackstone, D.L., Jr., Wyoming Geological Survey, Laramie, WY

Structural Geology of the Eastern Half of the Morgan Quadrangle, The Strouss Hill Quadrange, and the James Lake Quadrangle, Albany and Carbon Counties, Wyoming. Wyoming Geological Survey Preliminary Report No. 13; 45 pp. (1973, October)

The structural geology of the eastern half of the Morgan Quadrangle, the Strouss Hill Quadrangle, and the James Lake Quadrangle of Albany and Carbon Counties, Wyoming is detailed in this report. Uranium prospecting has been carried out in this area by several groups through the method of airborne scintillometers followed by drilling. Effort has been concentrated on the Paleocene Hanna Formation and the Eocene Wind River Formation, but to date, no ore bodies have been reported. (JMT)

<453>
Boudette, E.L., USGS, Reston, VA

Two-Mica Granite and Uranium Potential in the Northern Appalachian Orogen of New England. USGS Circular 753; Short Papers of the US Geological Survey Uranium-Thorium Symposium, 1977, J.A. Campbell (Ed.), (pp. 23-24), 75 pp. (1977)

The Concord Granite crops out in three belts in New Hampshire. The belts apparently coincide with antiformal flexures in allochthons which expose partial to complete sections of two-mica granite at least 1 km thick. The two-mica granite contains uranium minerals exposed in two parallel roadcuts along Interstate Route 89 in New London, N.H., and in the Lake Sunapee belt, the westernmost of the granite belts. The mineralized pluton is everywhere strongly jointed and is intensely sheared at a few places. The pluton has a moderate systematic foliation probably formed partly by flowage and partly by inherited relic foliation in screens dragged parallel to flowage. Oxidized uranium minerals in a zone more than 4 meters thick are exposed in the I-89 cut. This occurrence of secondary uranyl-phosphate minerals resembles that of the Daybreak mine near Spokane, Washington. Uranium minerals in the Lake Sunapee deposits occur mainly in fractures, local fault gouge, and biotitic schlieren. The granite is somewhat more fractured than correlative rock north and south on regional strike, but not conspicuously so. In the ten years since the mineralization was exposed by roadcuts and the water table was lowered, more than 90 percent of the yellow uranium minerals have been leached away by vadose ground water. It is possible that the uranium minerals have reprecipitated at the lower water table. Two-mica granite is recognized for its metallogenic specialization in tin, tungsten, beryllium, lithium, fluorine, and uranium. Uranium production in France and in the Iberian peninsula is from Variscan or Hercynian-age two-mica granites. The Concord Granite can be compared with the uranium-producing granites of the Massif Central of France and fits the evolving international model for two-mica granites based upon an apparent anatectic origin, emplacement during an orthotectonic event, and probable requisite preconcentration of uranium in its parent rock, thought to be migmatite. It is significant that carbonate-rich lamprophyre dikes are associated with the Concord Granite, especially as seen in the mineralized rock at Lake Sunapee. Carbonate lamprophyre emplacement in Variscan granites is concurrent with uraniferous vein emplacement and transformation of parts of the granite to episyenite, and the mobility of the uranium is related to carbonate complexing. Exploration on this basis should be focused on episyenite and lamprophyre zones, especially in the upper zones of the Concord sheets. (JMT)

<454>
Brown, K.B., Oak Ridge National Laboratory, Oak Ridge, TN

Chemical Technology Division, Chemical Development Section C, Progress Report for October-December 1961. ORNL-TM-137; 49 pp. (1962, February 21)

Results of research programs in the Chemical Technology Division of the Oak Ridge National Laboratory for the period of October through December 1961 are summarized in this report. Recovery of thorium by acid leaching ten granite samples (36-82 ppm) from the Conway Formation in New Hampshire ranged from about 50 to 95 percent, and averaged 70 percent. Study of the effect of grind size on the recovery of thorium from the Conway and Pikes Peak granites showed no significant differences in the range minus 20 to minus 200 mesh. The thorium concentration in a sized Conway granite sample was found to be much greater in the fine than in the coarse fractions, whereas the Pikes Peak granite showed only slight thorium enrichment in the finer fractions. Uranium recoveries in acid leaching of four different granite samples were not improved by adding an oxidant. Preliminary analysis of a field survey of the Conway granite indicated that the accessible surface of the formation averages at least 40 ppm thorium. The thorium concentration in twenty-two samples of sub-lateritic soil from Mississippi, Alabama, Georgia, and Virginia ranged between 5 and 16 ppm. (Auth)(JMT)

<455>
Campbell, J.A. (Ed.), USGS, Denver, CO

Short Papers of the US Geological Survey Uranium-Thorium Symposium, 1977. USGS Circular 753; 75 pp. (1977)

This circular contains expanded abstracts for 41 technical papers presented at the 1977 Uranium and Thorium Research and Resources Conference, sponsored by the Branch of Uranium and Thorium Resources of the US Geological Survey. The conference was held April 27 and 28, 1977, at the Colorado School of Mines, Golden, Colorado. All 41 papers have been abstracted and input into the National Uranium Resource Evaluation (NURE) Bibliographic Data Base. (JMT)

<456>
Dodge, M.M., and R.G. Loucks, Bureau of Economic Geology, Austin, TX

Mineralogical Composition and Diagenesis of Tertiary Sandstones along Texas Gulf Coast. AAPG Bulletin 63(3):440. (1979, March)

The upper Gulf Coast Wilcox Formation is composed dominantly of quartz with feldspar, metamorphic and volcanic rock fragments, and mud clasts. The lower Gulf Coast Wilcox Formation contains more quartz and volcanic rock fragments. Lower Gulf Coast Yegua and Jackson Formations are composed of quartz, volcanic, and lesser carbonate rock fragments. Northward they become more quartz-rich and contain metamorphic rock fragments and mud clasts. Lower Gulf Coast Frio and Vicksburg Formations are similar to the Yegua and Jackson. Northward, they become more quartz-rich, but carbonate rock fragments are absent. Despite variations in composition, Tertiary sandstones exhibit a similar diagenetic sequence idealized as follows. Surface to shallow subsurface diagenesis (0 to 4,000 ft; 1,200 m) begins with pedogenic clay coats and with leaching and calcite replacement of feldspar. Minor kaolinite, feldspar overgrowths, and iron-rich carbonate material are also precipitated. Porosity is commonly reduced by compaction from the original 40 percent to less than 30 percent. Moderate subsurface diagenesis (4,000 to 11,000 ft; 1,200 to 3,300 m) involves leaching of early carbonate cements and subsequent cementation by quartz overgrowths and later carbonate cement. These stages commonly reduce porosity to 10 percent or less, but this trend may be reversed by late leaching of feldspar, rock fragments, and carbonate cements. Restoration of porosity to more than 30 percent can occur, but this may be reduced by late cementation by kaolinite and iron-rich dolomite and ankerite. Deep subsurface diagenesis (11,000 ft; 3,300 m) is a continuation of late iron-rich carbonate cements. (Auth)

<457>
Graff, P.J., and R.S. Houston, USGS, Reston, VA

Radioactive Conglomerate in Proterozoic (Precambrian X) Metasedimentary Rocks of the Sierra Madre, Wyoming. USGS OFR-77-830; 9 pp. (1977)

A program of evaluation of miogeosynclinal metasedimentary rocks of the early middle Precambrian in southeastern Wyoming as possible host for uranium-bearing conglomerate was begun in 1975. The program was cooperative effort of the USGS, the University of Wyoming Geology Department, the Wyoming Geological Survey, and the Energy Research and Development Administration. The study has resulted in the discovery of uranium-bearing quartz-pebble conglomerates at several locations in the Mountain Bow Mountains and Sierra Madre. The most significant result of the 1977 field program was the discovery of radioactive conglomerate in the northwestern Sierra Madre. The quartz-pebble conglomerate beds of the western Sierra Madre are not uniformly mineralized with some layers having much higher uranium values than others. Although none of the analyzed samples from the Sierra Madre contained commercial quantities of uranium, the analyzed samples were taken from extensively weathered outcrops. Because uranium is very soluble in oxidizing solutions, it is probable that a significant amount of uranium present before weathering has been leached from these rocks. Speculation that economic concentrations of uranium may exist at depth have not been confirmed by exploration drilling. (JHT)

<458>
Leventhal, J.S., and H.C. Granger. USGS. Denver, CO

Conceptual-Mathematical Models of Uranium Ore Formation in Sandstone-Type Deposits. USGS Circular 753: Short Papers of the US Geological Survey Uranium-Thorium Symposium, 1977, J.A. Campbell (Ed.), (p. 38), 75 pp. (1977)

Relatively simple calculations allow estimates to be made of the time required to produce a sandstone-type ore deposit of a given size using reasonable assumptions for the removal of uranium from igneous source rocks, for uranium content of ground water, ground water flow rate, uranium entrapment efficiency, and host rock porosity and density. Mass balance calculations indicate that removal of half the uranium from a relatively small volume of source rock [7.7 x 10(E+5) cubic meters] having a specific gravity of 2.6 and originally containing 10 ppm uranium would yield 10 metric tons of uranium - approximately equal to a deposit that contains 26,000 pounds of U308. This amount is equivalent to that obtainable by weathering and leaching a 300 m x 300 m area of granite to a depth of 8.5 m or a 3 km x 3 km area of volcanic ash about 8.5 cm thick. The time required to remove the uranium from such source rocks depends, in part, on their porosity and permeability which, in turn, are related to either the grain size of the ash or the degree of fracturing of the granite, and, of course, the solubility of the uranium. The amount of weathering and rainfall and the infiltration of meteoric water into the ground water system also must be considered. It can be calculated that 10(E+9) cubic meters of water containing 10 ppb uranium are needed to form a deposits that contain 10 metric tons of uranium. If the rainfall is 25 cm/year, this amount of water would fall of the granite noted above in about 44,000 years and the ash in 440 years. In that it is unlikely that all the rainwater would enter the ground water system, these must be regarded as minimum estimates. If only 10 percent of the rainwater infiltrated the rock, the above time should be increased by a factor of 10. Using several reasonable assumptions, a calculation can be made of the time required to form a roll-type deposit that averages 5 m wide across the roll front and which contains 10 metric tons of uranium. If this deposit averages 0.25 percent uranium, it contains about 4,000 metric tons of ore, and if this ore has a specific gravity of 2, it has a volume of about 2,000 cubic meters. The 10(E+9) cubic meters of ore-bearing solution needed to supply 10 metric tons of uranium, assuming a uranium content of 10 ppb and 100 percent precipitation is about 500,000 times the volume of the ore deposit. The ore formed as the solution flowed through the 5-m-wide orebody. If the hydraulic gradient is 9.4 m/km and the host rock is a medium-grained sandstone having a permeability of 2 darcys, then the bulk of the water flow is 5.3 m/year. That is about 5.3 cubic meters of water flowing through a cross-sectional area of 1 square meter in a year. This means that each year a volume of water equal to the volume of ore percolates through the roll, and that it will take about 500,000 years to form the assumed 0.25 percent uranium orebody. If the ore solution were richer and contained as much as 50 ppb uranium, it then would take only about 100,000 years to form the same orebody. (Auth) (JMT)

<459>
Nelson, W.H., and J.P. Dobell. USGS. Washington, DC

Geology of the Bonner Quadrangle, Montana. USGS Bulletin 1111-F, (pp. 189-235). (1961)

The oldest rocks exposed in the Bonner quadrangle belong to the Newland Limestone, the local representative of the Piegan group. The group is characterized by the prevalence of calcite-rich rocks and is near the middle of the Belt Series. Here clayey and sandy tan to gray limestone is the major component of the Newland Limestone. The thickness of this area is at least 4000 feet. The Piegan group is succeeded upward by the Missoula group, which occupies most of the Bonner quadrangle. The Missoula group has an aggregate thickness of about 14,300 feet, and as subdivided here includes, from the base upward, the Miller Peak Quartzite, Bonner quartzite, McNamara argillite, Garnet Range quartzite, and Pilcher quartzite. All components of the Belt series within the quadrangle appear to have gradational contacts. The Miller Park argillite is composed of red and green silty argillite and argillaceous quartzite. The Hellgate quartzite member, high in the formation, is about 1200 feet thick, and has some 3800 feet of argillite below it and 1000 feet of argillite above. The Bonner quartzite corresponds to the middle member of the McNamara formation. The formation is characterized by its tendency by break into blocks specked with grains of white, translucent, weathered feldspar. Pink vitreous quartzite predominants the formation and it is about 1500 feet. The McNamara argillite, as here restricted, is composed largely of red and green metamorphosed clayey siltstone and minor amounts of argillite and quartzite. The formation is about 4000 feet thick. The Garnet Range quartzite consists of greenish-gray quartzite and dark-green and dark-gray argillite, shale, and sandy argillite. The color, abundant detrital mica, and intense internal deformation serve to distinguish the formation. The formation is about 1800 feet thick. The next succeeding formation is well exposed along Pilcher Creek, and is here named the Pilcher quartzite. Most of the formation consists of pale- to moderate-red crossbedded quartzite. The Pilcher quartzite is from 700 to 1800 feet in thickness. The contact between the Missoula group and the overlying rocks may be either gradational or unconformable. The overlying rocks are probably of Middle Cambrian age. Cirques, U-shaped valleys, and small moraines in the northern part of the quadrangle indicate glaciation during Pleistocene time. Shoreline features at many places below an altitude of 4200 feet testify to the former glacial Lake Missoula. Sills, dikes, and stocklike bodies of diabase of probable late Precambrian age constitute the only intrusive masses within the mapped area. (Auth) (JMT)

<460>
Robertson, F.S., University of Washington,
Seattle, WA

Geology and Mineral Deposits of the Ellison Mining District Powell County, Montana. Ph.D. Thesis; 332 pp. (1956)

The Elliston mining district comprises an area of about 85 square miles, about 20 miles southwest of Helena, Montana. Sedimentary rocks, Mississippian to Lower Cretaceous, crop out in a small area in the northeast part of the district. Upper Cretaceous volcanic rocks occur throughout the northwestern two-thirds of the district where they rest unconformably on sedimentary rocks. The Boulder Batholith intruded the volcanic rocks probably in very early Tertiary time and is represented by granodiorite followed by main stage quartz monzonite with related aplite-alaskite. The structural events in the district are: 1) very mild warping and erosion prior to the early volcanics, 2) westerly tilting of sedimentary and volcanic rocks, 5 to 30 degrees, prior to and/or accompanying intrusion of the batholith, 3) intrusion of the Boulder batholith, followed by 4) faulting, jointing, and vein formation, all tectonically related. Veins in the quartz monzonite were formed by many stages of fracturing. Early replacement lodes were followed by successive fissure fillings. The common vein minerals are in order: tourmaline, quartz, pyrite, auriferous arsenopyrite, sphalerite, argentiferous galena, argentiferous tetrahedrite, chalcopyrite and ankeritic carbonates. Fissure veins in volcanic rocks are generally narrow and include: 1) steep N. 65 degrees E. veins, 2) steep veins parallel to NE faults, and 3) "flat" veins. The mineralogy is the same as above except for tourmaline. The mineralogical and petrological features, as well as chemical variation diagrams, suggest consanguinity of the batholithic and Upper Cretaceous volcanic rocks. The volcanic pile is considered to represent the first magmatic episode which was followed by the intrusion of quartz monzonitic magma in an essentially concordant body of batholithic dimensions. Batholithic rocks were exposed by erosion in early Tertiary time. An upland surface was developed which is now at about 7,200 feet. Rhyolite welded tuffs were extruded onto the partly dissected surface. The age of the rhyolite is not known, but a late Tertiary age is possible. Two stages of glaciation, one possibly pre-Wisconsin and another probably early Wisconsin are recognized. (JHT)

<461>
Roth, R.

Paleogeology of the Panhandle of Texas. Bulletin of the Geological Society of America 60:161-168. (1949, October)

The sedimentary sequence and facies changes in the subsurface of the Panhandle of Texas are shown by three cross-sections. The stratigraphic column is divided into 13 geologic subdivisions. A paleogeologic map presents the areal distribution of each geologic subdivision. The effects of orogenic and epeirogenic movements are discussed. (Auth) (MBW)

There are numerous maps included in this report; Cited as a reference in NURE Contractor Reports.

<462>
Wallace, A.R., and J.W. Cady, USGS, Denver, CO

Geophysical and Petrologic Studies of Radioactive Contact Zones of Pyroxenite Dikes in Nepheline Syenite of the Ekiek Creek Pluton, Western Alaska. USGS Circular 753; Short Papers of the US Geological Survey Uranium-Thorium Symposium, 1977, J.A. Campbell (Ed.), (pp. 6-8), 75 pp. (1977)

A ground geophysical, petrographic, and petrophysical study was made of the Ekiek Creek pluton in western Alaska to determine the sources of coincident total-count gamma-ray and aeromagnetic anomalies detected in aerial surveys. The Ekiek Creek pluton is a composite stock of Cretaceous age which intruded Lower Cretaceous silicic stocks and volcanic rocks. It includes two major silica-undersaturated rock types; fine-grained pyroxenite and medium-grained nepheline syenite. Field relationships between the two are anomalous. Petrographic studies of the samples collected in the field show a metamorphosed contact zone in addition to unaltered pyroxenite and nephline syenite. The felsic rocks contain major orthoclase and nepheline, and varietal biotite, aegerine, and sphene. The pyroxenites are fine- to medium-grained in thin section, and are composed of predominant aergerine-augite and biotite, and minor orthoclase, nepheline, sphene, and zeolites. In contact zones, poikiloblastic mafic minerals commonly contain inclusions of fine-grained melanite and orthoclase. The orthoclase and garnet become more common near the syenite. Gamma-ray spectrometer traverses show zones of highest radioactivity alone contacts between pyroxenite and nepheline syenite. Iron oxide staining, perhaps indicating hydrothermal alteration, is prominent along the contact zones. Detailed profiling by gamma-ray spectrometry showed the iron oxide-stained rocks are more radioactive than average, but the highest readings were obtained over a sharp, unoxidized contact of pyroxenite against nepheline syenite. On a scale of kilometers, aeromagnetic highs of the Ekiek Creek pluton and of other alkalic plutons north of the Selawik Hills correlate with radioactivity anomalies. On a scale of 10 to 100 meters, radioactivity anomalies correlate with contact zones between pyroxenite and nepheline syenite. The pyroxenite is distinguised by magnetic and VLF conductivity highs. Thus magnetic and electrical measurements, on either scale, may be tools for locating possible uranium mineralization. (JHT)

<463>
Warren, C.G., USGS, Denver, CO

Ground-Water Flow and the Shape of Uranium Roll Deposits. USGS Circular 753; Short Papers of the US Geological Survey Uranium-Thorium Symposium, 1977, J.A. Campbell (Ed.), (pp. 24-25), 75 pp. (1977)

The characteristics of ground water flow were related to the shape of the oxidation front of sandstone-type orebodies in an effort to use this relationship as a tool for studying the ground water flow during the time that the deposit was forming. Many ground water flow patterns were evaluated to find the associated shape of the oxidation front. The type of ground water flow that produced shapes similar to those found in actual deposits was postulated to represent the actual flow of ground water as the deposits formed. The oxidized tongue associated with a roll-type uranium deposits was created by oxidants reacting with the pyrite and other ore components. The rate at which the oxidized tongue advanced was controlled by the rate at which the oxidants were delivered to the oxidation front. Although all oxidants were delivered by ground water there were two separate and distinct processes involved: (1) oxidants were transported by the moving ground water, (2) oxidants were moved by diffusion from regions of high concentration to regions of low concentrations. These delivery processes were described by a differential equation and solved by computer analysis. The results were displayed on microfilm in a graphical form resembling the shape of a roll front of an actual orebody. A movie showing the development of an oxidation from and uranium ore body was obtained by recording successive computer-generated representations of the roll front. In the movie, a bulge or roll develops in the oxidation front within the zone of maximum flow in the aquifer. Although parts of the orebody may lag behind in the less permeable zones of the aquifer, they are slowly destroyed by oxidants that are delivered by the diffusion process. In a simple homogeneous aquifer system the shape of the roll gradually achieves maturity and its dimensions are a function of the ratio between flow velocity and diffusion. For example, an average ground water velocity of 2x10(E-5) cm/s (6.3 m/yr) and an oxidant diffusion coefficient of 2x10(E-5) cm/s will produce a C-shaped oxidation front with a profile about twice as wide as the height of the aquifer. (Auth) (JRT)

<464>
Wilbert, W.P., and C.J. Templain, Bendix Field Engineering Corporation, Grand Junction, CO

Preliminary Study of Uranium Favorability of the Wilcox and Claiborne Groups (Eocene) in Texas. GJBX-7(78); 25 pp. (1978, January)

Rocks of the Wilcox and Claiborne Groups crop out in the Texas Gulf Coastal Plain and are represented by a series of sands and shales which reflect oscillation of the strandline. The Wilcox Group (lower Eocene), usually undifferentiated in Texas, consists of very fine sands and clays and abundant lignite. The Claiborne Group (middle Eocene) comprises, in ascending order, Carrizo Sand, Reklaw Formation (clay), Queen City Sand, Weches Formation (clay), Sparta Sand, Cook Mountain Formation (clay), and Yegua Formation (sand). Fluvial systems of the Wilcox and Claiborne exist in east Texas and trend perpendicular to the present coastline. In central Texas, sand bodies are parallel to the present coastline and are strand-plain, barrier-bar systems. Since the time of deposition of the Queen City Sand, a significant fluvial sand buildup occurred in the area of the present Rio Grande embayment where the marine clays pinch out. Known occurrences of mineral matter in the Wilcox and Claiborne (up to the Yegua) are limited to lignite (particularly in the Wilcox), channel coal in the upper Claiborne, and hydrocarbons throughout. No uranium mineralization is known, and no uranium is likely to be discovered in the Claiborne and Wilcox. Approximately 50 surface samples and many gamma-ray logs showed no significant anomalies. The sands are very good potential host rocks, but no uranium source was discovered. During deposition of the Wilcox and Claiborne Groups, there was no volcanism to serve as a source of uranium (as with the prolific occurrence in the younger rocks of south Texas); also, Precambrian crystalline rocks in the Llano uplift were not exposed. (Auth)

<465>
Ajuria-Garza, S., and S. Constantino-Herrera, Instituto Nacional de Energia Nuclear, Mexico City, Mexico

Exploration, Mining, and Milling of Uranium Ore in Mexico. CONF-761014; Nuclear Power Development and the Fuel Cycle, F. Parmakes (Ed.), Proceedings of a Conference, Honolulu, HI, October 11-14, 1976. American Nuclear Society, Incorporated, Hinsdale, IL, (pp. 215-222). (1976)

About 95 percent of the total area of Mexico is regarded as favorable for geological and geophysical uranium exploration, but less than 10 percent of this area has been or is being actively explored for uranium. As of December 1975, the total positive reserves in Mexico were 8000 metric tons of U3O8. This figure is expected to increase considerably with increased exploration. The discovery of substantial uranium reserves in acidic volcanic rocks has been a significant development in Mexico. Previously, this type of rock was not considered as a suitable geologic environment for uranium. About 63 percent of the Mexican uranium reserves are in Cretaceous limestones and Tertiary volcanic rocks. Only 37 percent of the reserves are in sandstones and arkoses of sedimentary origin. Three uranium mills represent Mexico's effort in uranium ore processing: one which operated from 1969 to 1971 and produced 49 metric tons of U3O8, one under construction, and one in the initial planning stage. (JBT)

<466>
Cook, E., Texas A & M University, College Station, TX

Exploitation of Very Low-Grade Uranium Deposits. AAPG Bulletin 63(3):435. (1979, March)

Where once there was great optimism about the economic exploitation of very low-grade uranium deposits (0.002 to 0.010 percent U3O8) such as occur in the Chattanooga Shale and the Conway Granite, there now is almost equivalent pessimism. A 1978 National Research Council report "rules out" shales and granites as future uranium sources, because of the "enormous" mining and processing costs required and because the environmental impacts of the "many huge operations" that would be needed are not likely to be acceptable. Such a conclusion appears premature. Gold is won at an after-tax profit from deep-mined refractory ores in which it is found in concentrations as low as 3 ppm (0.0003 percent), much lower than the low end of the range cited for uranium in shales and granites; the price-grade relations for gold suggest that 0.006 percent U3O8 rock could become ore at a price well below $150/lb. The energy balance appears positive even for once-through LWR burning; with breeders, it would be strongly positive. To meet the projected 1980 United States annual requirement of 19,000 short tons of U3O8 from a single mine in rock containing 0.006 percent U3O8 at 70 percent recovery would require moving a minimum of 1.24 million short tons of rock a day--a large amount, but easily within the ability of present technology (5 or 6 large copper pits would be the equivalent), and possibly not unacceptable in a time of energy scarcity. The major constraint on potential uranium supply remains political, rather than geological or technological. (Auth)

<467>
Griffith, J.W., A.E. Lang, S.C. Robinson, S.M. Roscoe, and H.R. Steacy, Canada Geological Survey, Ottawa, Ontario, Canada

Types and Ore Reserves of Canadian Radioactive Deposits. Peaceful Uses of Atomic Energy, Vol. 2, Survey of Raw Material Resources, Proceedings of the 2nd International Conference, Geneva, Switzerland, September 1-13, 1958. United Nations, New York, (pp. 35-39), 543 pp. (1958)

Production of uranium oxide in Canada in 1957 was estimated to total 6697 tons, valued at $136,700,000. Uranium-bearing conglomerate in the Blind River region, Ontario, accounted for 51 percent of the Canadian production in 1957. Pitchblende-bearing veins and disseminations in the Beaverlodge region, Saskatchewan, and Great Bear Lake and Marian River regions, Northwest Territories, provided 41 percent. Dykes and lenses of pegmatitic granite in the Bancroft region, Ontario, yielded 8 percent. There are twelve general types of uranium deposits in Canada. They are as follows: 1) granites and syenites, 2) pegmatites, 3) metasomatic deposits, 4) hydrothermal deposits, 5) placers, 6) conglomerates, 7) sandstones, 8) dolomites, 9) phosphate rocks, 10) carbonaceous deposits, 11) cappings, and 12) deposits formed by percolating water. Total measured, indicated, and inferred uranium reserves in Canada total 376,998,000 short tons. Thorium has been found in many classes of uranium deposits; in some occurring in larger amounts than uranium. The principal known deposits of thorium in Canada are the uranium ores of Blind River. These are estimated to contain an average of 0.05 percent ThO2. Some large deposits in this district appear to average 0.1 percent ThO2, and ores now being mined near Bancroft are estimated to carry about 0.02 to 0.2 percent ThO2. Deposits of several other kinds contain large tonnages of very low grade thorium-bearing material. The principal ones known are dolomite containing monazite, and placers containing various thorium minerals. Virtually no prospecting has been done in Canada directly for thorium. If this should be warranted, it seems probable that other large deposits, perhaps of higher grade, might be found. (JBT)

<468>
Hickman, R.C., and V.J. Lynch, Bureau of Mines, Washington, DC

Chattanooga Shale Investigations. Bureau of Mines Report of Investigations 6932; 55 pp. (1967, April)

Preliminary evidence indicated that the Chattanooga Shale might constitute a potential vast low-grade source of uranium. Investigation by core drilling indicated that while the Chattanooga Shale may constitute a resource for the future, the very low (0.006 percent) average uranium content is not economic when compared with the relatively higher grade western ores. A total of approximately 12,000 feet of test drilling was done in 72 drill-holes, and large samples were mined for extractive and metallurgical testing. An experimental mine site was selected on the basis of the drilling project. (Auth)

RESERVES AND RESOURCES

<469>
Johnson, J.C., AEC, Division of Raw Materials, Washington, DC

Resources of Nuclear Fuel for Atomic Power. Peaceful Uses of Atomic Energy, Vol. 2, Survey of Raw Material Resources, Proceedings of the 2nd International Conference, Geneva, Switzerland, September 1-13, 1958. United Nations, New York, (pp. 3-6), 843 pp. (1958)

Uranium reserves fall into two broad economic categories: those from which uranium could be recovered and sold profitably at a price of approximately $10 per pound of U308 or less; and the very low-grade uraniferous shale and phosphate deposits from which exploitation for uranium alone would require a price three to six times that amount. With respect to reserves of the first category, the 1957 estimates by Canada and South Africa indicate that the developed or partially developed reserves in each of these two countries contain approximately 400,000 tons of U308. Recorded reserves of the United States are now about 220,000 tons. Nearly two years ago, France published reserve figures of 50,000 to 100,000 tons. These estimates total about 1,100,000 tons of U308. Taking into consideration the probable conservative nature of these estimates, and including the reserves of Australia, the Belgian Congo, Portugal and other countries, total reserves in areas presently under development in non-Communist countries may be nearer 1,500,000 tons of U308. On the basis of present geologic data, and the discovery experience of the past ten years, an additional 2,000,000 tons of relatively low-cost uranium might be developed in new areas within a reasonable period by an aggressive exploration program. A major factor responsible for the lack of discovery of many new areas since 1955 has been the limited market for additional uranium production. The United States, Canada, and South Africa are the major producing countries. Production in the United States, is now about 15,000 tons of U308 per year. The production rate in Canada is approximately 13,000 tons a year, and South African production is more than 6,000 tons of U308 per year. The cost of mining uranium ores in the USA varies widely. Large, open-pit mining operations are increasingly important, and mining costs range from $4.80 to $11.50 per ton (1959). Underground mining costs range from $6.00 to $10.00 for large mechanized operations to about $15.00 per ton for small underground operations. The cost of processing sandstone-type ores in the USA ranges from $6.00 to $10.00 per ton for the larger mills. (JRT)

<470>
Nininger, R.D., DOE, Rockville, MD

Future of Uranium. AAPG Bulletin 63(3):503. (1979, March)

The future of nuclear power has been uncertain for a number of years. However, despite somewhat lower forecasts than some years ago, nuclear is emerging again as a major future power source both in this country and throughout the world. Uranium is the mainstay of nuclear power whether alone or in combination with plutonium. If nonproliferation concerns dictate the former, much larger quantities of uranium will be needed than otherwise but, in either case, a many-fold increase in production will be required. Additional uranium resources are being developed in the United States and the world at an adequate rate for the time being, but this rate will have to be increased substantially toward the latter part of the century. United States reserves calculated at a forward production cost of U308 increased in 1978 by about the same amount as in 1977. Total estimated resources did not change significantly, however, and exploration activity has apparently begun to level off at least for the present. The development of uranium deposits in Texas and successful exploration to expand Texas uranium resources can play a significant, although probably not major, role in meeting United States uranium demand. (Auth)

<871>
Offield, T.W., G.L. Raines, and D.L. Sawatzky, USGS, Denver, CO

Computer-Enhanced Images and Geologic Studies, Southern Powder River Basin, Wyoming. USGS Circular 753; Short Papers of the US Geological Survey Uranium-Thorium Symposium, 1977, J.A. Campbell (Ed.), (pp. 27-29), 75 pp. (1977)

Different surface geologic materials of interest in uranium exploration show varying reflectance characteristics and vegetation assemblages in computer-enhanced Landsat images of the southern Powder River Basin. Well drained (sandy, coarse-grained) and poorly drained (clayey, fine-grained) soils are distinguished by conspicuous vegetation differences; a major vegetation change marks the line drawn by some mappers for the disputed contact of the Fort Union and Wasatch Formations. Within the area underlain by generally coarse-grained sandstones of the Wasatch, numerous areas have vegetation like that of the Fort Union, suggesting the presence of the Fort Union or finer grained facies in the Wasatch. Color enhancements of images produced from single ratios is achieved by compositing three color films each of which represents contrast stretches of three different segments of the image gray scale. This and other enhancements of the band 4 to band 5 ratio image, especially when combined with enhanced versions of other band-ratio images, permit reasonably good discrimination of exposed hematite stained materials in altered ground associated with uranium roll-front mineralization. The vegetation differences and red altered ground are not discernible in available high-altitude, color-infrared photographs. Field and laboratory measurements of spectral reflectance show that absorption bands characteristic of ferric iron are obvious in spectra of altered rocks and their overlying residual soils, but are absent or minimal in the spectra of unaltered materials. This is the basis of the detection of red altered ground using Landsat data. The field spectra show that bands not available on Landsat but available in aircraft scanners should permit better discrimination of hematite-stained, altered materials and possibly of calcite-cemented materials associated with uranium roll fronts. Enhanced Landsat images also show many linear topographic elements 2 to 25 km long that are so regularly developed that they are inferred to represent geologic structure. Lineaments in the southern Powder River Basin match the northwest trend of subsurface fold and ore-sand isopachs mapped at the Highland mine. A color-enhanced image of a Landsat band 5 to band 6 ratio has revealed a NNW-trending lineament marked by changes in vegetation and stream-course patterns. The line is suspected of marking a subtle, relatively young structural sag parallel to and west of a postulated positive fold axis. Uranium occurrences are scattered in a narrow belt west of this newly defined lineament, but the line marks the west limit of economic mineralization thus far discovered. The authors believe the lineament represents a structural sag that impeded the flow of uranium-bearing solutions and promoted major uranium deposition just east of the structure. (JST)

<872>
Reed, J.H., and G.H. Reynolds, Science Applications, Incorporated, La Jolla, CA

Gamma-Ray Spectrum Enhancement. GJBX-25(77); SAI-77-518-LJ; 98 pp. (1977)

The results of a program to apply the MAZE code to the analysis and enhancement of gamma-ray spectra from airborne large-volume NaI detection systems is described. The program improves on the accuracy of uranium, thorium, and potassium determinations and picks out Bi 214 peaks (other than 1.76 MeV) for possible use in correcting for airborne Bi 214 background. The MAZE development improves the accuracy of other gamma-ray spectroscopy performed in the exploration of uranium using either borehole or surface KUT (potassium, uranium, thorium) detection. (PAG)

<873>
Stockdale, P.B., University of Tennessee, Department of Geology and Geography, Knoxville, TN

An Investigation of the Chattanooga Black Shale of Tennessee as a Source of Uranium. ORO-143; 11 pp. (1955, July 1)

Seven hundred fifty-two outcrop samples and one hundred thirty core samples of the Chattanooga Shale were collected for uranium analysis. Fluorimetric uranium analyses were run on all samples, supplemented by flame spectrophotometric analyses for ferric oxide, calcium oxide, and other trace elements apt to be present. The phosphate content was also determined in some instances. Calculations of the uranium reserves in all of the Chattanooga Shale which lies beneath the 15,000 square miles of the Highland Rim and the Cumberland Plateau of the state of Tennessee produce a figure of approximately 20,000,000 tons of uranium. This figure assumes an average thickness of 25 feet for the Chattanooga Shale, and an average grade of 0.0025 percent uranium. The best average uranium grade in the Chattanooga Shale is in the Gassaway Member. Conclusions were fairly well established regarding the amount of uranium in the Chattanooga Shale. They are as follows: (a) the amount of uranium is reasonably consistent from place to place, and there are not abrupt lateral differences at any given stratigraphic horizon; (b) the Gassaway Member is higher grade than the Dowelltown Member; (c) the "E" unit of the Gassaway Member, where distinguishable, runs the highest of the individual units, with 0.008 percent uranium, or better; (d) the "B" unit, with its many gray beds, is the poorest, commonly running no greater than 0.001 to 0.0015 percent uranium; and (e) the "A", "C", and "D" units of the Gassaway Member are of intermediate grade. (JET)

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<871>
Wright, R.J., DOE, Washington, DC

New Mexico and World Uranium. AAPG Bulletin
63(4):695. (1979, April)

New Mexico is endowed with the world's largest known concentration of uranium ore in sandstone. Through 1977 these orebodies yielded 129,150 short tons of U3O8, about 41 percent of the United States supply and 10 percent of the free world's supply of yellow cake. Only one foreign nation, Canada, exceeds the state of New Mexico in production. From the 1977 level of about 7,600 tons U3O8, New Mexico's output is expected to double within the next 10 years, thus maintaining the state's relative position within the United States. However, the nation's share of world production is apt to slip as new mines come on-stream in such countries as Australian, Canada, and Niger. The sandstone uranium deposits of New Mexico, Colorado, Wyoming, and Texas have provided models for exploration around the world, and orebodies of this type are now known in at least 10 countries. Some of the foreign deposits exhibit unusual geologic features or have distinctive exploration histories. Argentina-At Sierra Pintada, the largest deposit, the ore is related to pyrite in an eolian sandstone. Australia-In the Beverly basin ore was discovered by drilling continental sediments flanking Mt. Painter which contains uranium-bearing veins in granite. Austria-At Forstau, pitchblende and coffinite mineralization in Permian sandstone beds was not remobilized during regional metamorphism to the greenschist facies. Canada-The Blizzard deposit of British Columbia was found by application of the Tono, Japan, model. France-The Herault deposit, in Permian sediments, is controlled partly by faults and partly by lithology. Gabon-The deposits are in the oldest host rock (about 2,000 m.y.) known to contain sandstone ore. Japan-In the Tono deposit, the ore is contained in paleochannel structures as a uranium-bearing zeolite mineral. Niger-The largest resources in sandstone, exclusive of the United States, have been developed in Niger. South Africa-The main deposits are in the lower part of the Beaufort Group (of the Karoo Supergroup), but northward the deposits are progressively higher in the section and in younger rocks. (Auth)

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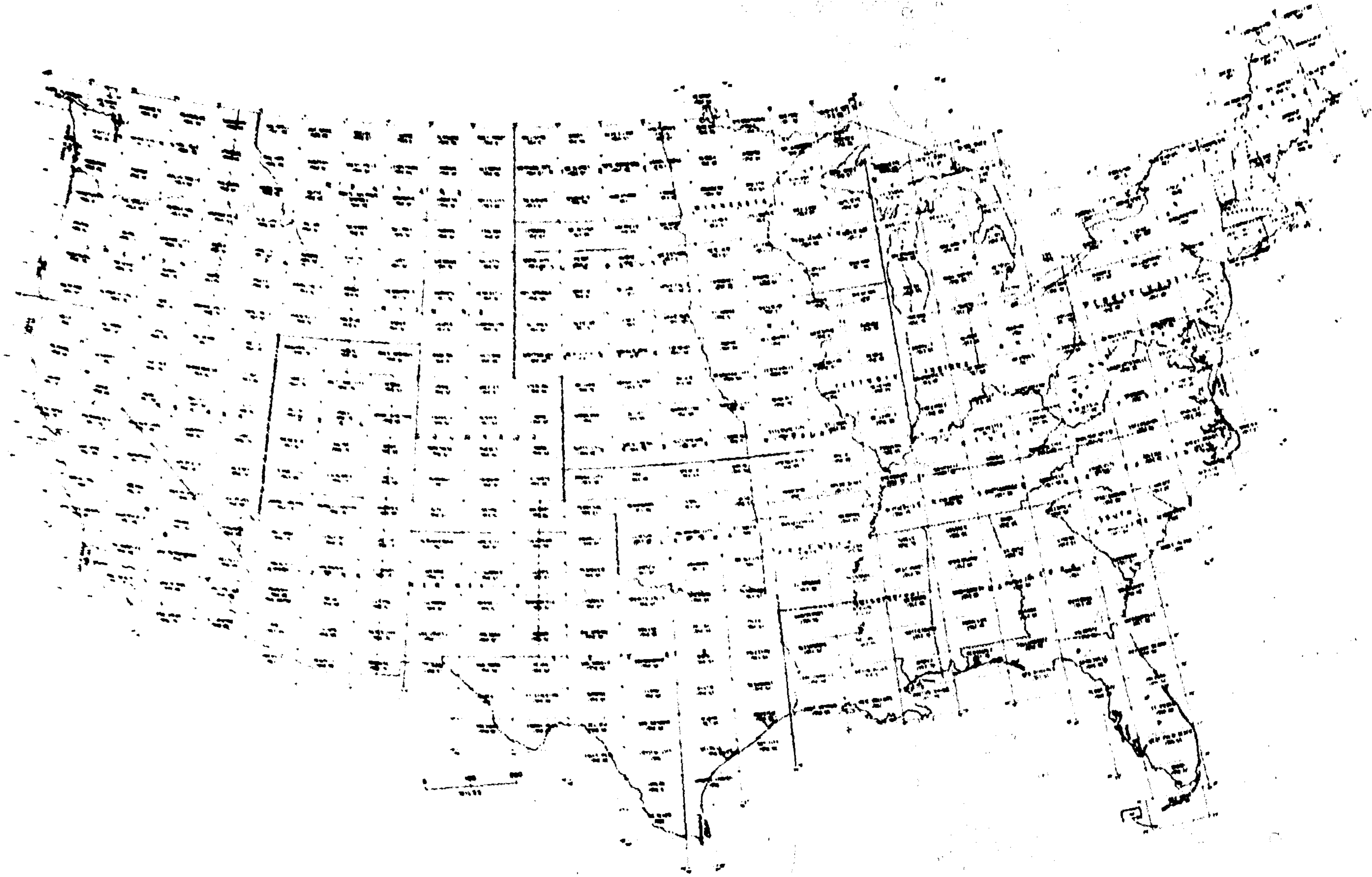

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